

BEHAVIOURAL ECONOMIC STUDIES  
OF TOBACCO CONTROL: EXCISE TAX,  
ALTERNATIVE PRODUCTS, AND  
APPLICATION TO PRIORITY POPULATIONS  
IN NEW ZEALAND

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## TABLE OF CONTENTS

Acknowledgements	i
Abstract	ii
List of Figures	v
List of Tables	vii
List of Supplementary Material	viii
<b>1. Introduction</b>	<b>1</b>
1.1. Background	1
1.2. Thesis Overview	3
<b>2. Literature Review</b>	<b>7</b>
2.1 Nicotine Dependence	7
2.1.1. A behavioural economic perspective	9
2.2. Price Policy	10
2.2.1. Economic studies of price policy	11
2.2.1.1. Economic studies in New Zealand	13
2.2.2. Behavioural economic studies of price policy	16
2.2.2.1. Demand curve analysis	18
2.2.2.1.1. The exponential model	18
2.2.2.1.2. The modified exponentiated model	19
2.2.2.1.3. Metrics from demand curve analysis	19
2.2.2.2. Purchase task studies	20
2.2.3. Summary and application to New Zealand	23
2.3. Alternative Products	24
2.3.1. Measuring subjective effects	26
2.3.2. Measuring demand	26
2.3.3. Novel alternative products in New Zealand	28
2.3.3.1. Very Low Nicotine Content (VLNC) cigarettes	28
2.3.3.1.1. Subjective effects	31
2.3.3.1.2. Demand	32
2.3.3.1.3. Summary and application to New Zealand	34
2.3.3.2. Electronic cigarettes	36
2.3.3.2.1. Subjective effects	40
2.3.3.2.2. Demand	43

## TABLE OF CONTENTS

2.3.3.2.3. Patterns of behaviour	47
2.3.3.2.4. Summary and application to New Zealand	51
2.4. Summary and Outline of Studies	53
<b>3. Changes To Smoking Habits And Addiction Following Tobacco Excise Tax</b>	<b>55</b>
<b>Increases: A Comparison Of Māori, Pacific And New Zealand European Smokers</b>	
3.1. Preface	55
3.2. Abstract	56
3.3. Introduction	57
3.4. Method	61
3.4.1. Participants	61
3.4.2. Procedure	61
3.4.3. Measures	62
3.4.4. Statistical analysis	62
3.5. Results	65
3.6. Discussion	71
<b>4. Using A Cigarette Purchase Task To Assess Demand For Tobacco And Nicotine-Containing Electronic Cigarettes For New Zealand European And Māori/Pacific Island Smokers</b>	<b>77</b>
4.1. Preface	77
4.2. Abstract	78
4.3. Introduction	79
4.4. Method	83
4.4.1. Participants	83
4.4.2. Procedure	84
4.4.3. Measures	84
4.4.3.1. Cigarette Purchase Task	84
4.4.3.2. NEC sampling and questions	85
4.5. Results	86
4.6. Discussion	92
<b>5. Estimating Demand And Cross-Price Elasticity For Very Low Nicotine Content (VLNC) Cigarettes Using A Simulated Demand Task</b>	<b>98</b>
5.1. Preface	98

## TABLE OF CONTENTS

5.2. Abstract	99
5.3. Introduction	100
5.4. Method	104
5.4.1. Participants	104
5.4.2. Procedure	104
5.4.3. Measures	104
5.5. Results	107
5.5.1. Participant characteristics	107
5.5.2. Favourability	108
5.5.3. Simulated demand	109
5.6. Discussion	116
5.7. Supplementary Material 1	122
<b>6. Subjective Effects And Simulated Demand For Electronic Cigarettes In First-Time Users: Effects Of Nicotine Level</b>	<b>124</b>
6.1. Preface	124
6.2. Abstract	125
6.3. Introduction	126
6.4. Method	128
6.4.1. Participants	128
6.4.2. Procedure	128
6.4.3. Measures	129
6.4.3.1. Online questionnaires	129
6.4.3.2. Session measures	130
6.4.4. Data analysis	130
6.5. Results	131
6.5.1. Participant characteristics	131
6.5.2. Subjective ratings	132
6.5.3. Demand	135
6.6. Discussion	138
6.7. Supplementary Material 1	143
6.8. Supplementary Material 2	145
6.9. Supplementary Material 3	148

## TABLE OF CONTENTS

<b>7. Predicting Short-Term Uptake of Electronic Cigarettes: Effects of Nicotine, Subjective Effects and Simulated Demand</b>	<b>150</b>
7.1. Preface	151
7.2. Abstract	152
7.3. Introduction	155
7.4. Method	155
7.4.1. Participants	155
7.4.2. Procedure	156
7.4.3. Measures	156
7.5. Results	157
7.5.1. Participant characteristics	157
7.5.2. E-cigarette uptake and changes in smoking behaviour	159
7.5.2.1. Daily e-cigarette use	159
7.5.2.2. Cigarettes per day	159
7.5.3. Subjective effects	160
7.5.4. Predicting uptake with subjective effects	163
7.6. Discussion	164
<b>8. General Discussion</b>	<b>169</b>
8.1. The Role of Psychology & Behavioural Economics in Tobacco Control Research	169
8.1.1. Measuring demand for cigarettes	170
8.1.2. Measuring demand for alternative products	171
8.1.3. Utility of subjective effects measures	173
8.2. Strengths and Limitations	174
8.3. Implications for Tobacco Control Policy	175
8.3.1. Utility and policy implications of price policy	175
8.3.1.1. Implications for price policy in New Zealand	177
8.3.2. Utility and policy implications of VLNC cigarettes	178
8.3.3. Utility and policy implications of e-cigarettes	180
8.3.3.1. E-cigarettes and tobacco control in New Zealand	182
8.3.4. Implications for a comprehensive nicotine and tobacco policy	184
8.4. Future directions	185
8.5. Conclusions	188

## TABLE OF CONTENTS

<b>9. References</b>	190
Appendix 1: Publications and Conference Proceedings	218
Appendix 2: Ethics Approval Documentation	219

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## ABSTRACT

### Objectives

Tobacco control is a multidisciplinary field which uses theory and research from medicine, public health, economics and psychology in an attempt to reduce the harm associated with tobacco cigarette smoking, a leading cause of preventable death in most developed countries. This thesis uses a psychological approach to study potential tobacco control policies relevant to New Zealand, primarily based on the psychology of addiction and the behavioural economic analysis of price policy and alternative products. Specifically this research is the first to use simulated demand procedures to compare price sensitivity for Māori/Pacific and New Zealand European smokers, and to compare ratings and substitutability of e-cigarettes between these ethnic groups. In addition, the first evaluations of simulated demand and subjective effects for Very Low Nicotine Content cigarettes and for varying nicotine levels in electronic cigarettes are reported. Finally, simulated demand and short-term uptake of electronic cigarettes are modelled using a combination of two subjective effects measures, representing the first attempts to model how initial experience of electronic cigarettes affects intended and actual use of these products.

### Methods

Five empirical studies use behavioural economic simulated demand procedures and psychological measures of dependence, smoking behaviour and subjective effects to examine the potential impact of price policy and alternative products on demand and smoking-related behaviour. The first two studies use data from the Cost of Smoking Study [ $N=357$ ], a survey of smokers from four New Zealand cities who responded in 2012, 2013 and 2014, before and after two annual 10% tobacco excise tax increases. Group comparisons were performed to compare Māori/Pacific and New Zealand European smokers. Two original laboratory studies assessed subjective effects, simulated demand, and substitutability of alternative products



after a brief *ad libitum* sampling period. Very Low Nicotine Content cigarettes were compared with regular cigarettes [ $N=40$ ], and electronic cigarettes of varying nicotine contents were compared [ $N=46$ ]. The Modified Cigarette Evaluation Questionnaire was used to evaluate subjective effects associated with smoking, and hypothetical purchase tasks were used to generate simulated demand data. Finally, a follow-up field trial examined subjective effects, smoking behaviour and electronic cigarette use over a two week period when e-cigarettes of varying nicotine contents were available [ $N=35$ ]. Mixed model analyses were used to assess use of both products, and to model e-cigarette use using subjective effects data.

## Results

The exponentiated demand model provided good fits for simulated demand data for regular cigarettes, Very Low Nicotine Content cigarettes and electronic cigarettes, for Māori/Pacific and New Zealand European smokers. Māori/Pacific smokers, especially males, appeared to be more price sensitive based on reported actual behavioural change after two excise tax increases, and simulated demand data. Very Low Nicotine Content cigarettes were partially substitutable [ $CPE=.32$ ] but had reduced reinforcing effects relative to regular cigarettes. Electronic cigarettes were partially substitutable for regular cigarettes regardless of nicotine content [ $CPE=.20-.25$ ] but subjective effects and demand varied by nicotine content for first-time users; withdrawal symptom alleviation increased as nicotine increased but taste and enjoyment factors decreased. Smokers appeared to balance withdrawal symptom alleviation and taste and enjoyment factors in the hypothetical choice to purchase electronic cigarettes, and lower nicotine content cartridges were valued the most. After a two week period of use, nicotine-containing electronic cigarettes were reported to reduce craving more than non-nicotine cartridges, and were used more over this period. A combination of withdrawal symptom alleviation and taste and enjoyment factors predicted both simulated

demand after brief, first-time exposure and short-term electronic cigarette use over a two-week period.

## **Conclusions**

These studies demonstrate the utility of psychological and behavioural economic methods for contributing to tobacco control research. The findings suggest that product characteristics that influence subjective effects and price mechanisms could increase the uptake of novel alternative products (Very Low Nicotine Content cigarettes and electronic cigarettes) to ultimately reduce cigarette smoking behaviour. The results highlight the potential for price policy and the availability of nicotine-containing electronic cigarettes to reduce smoking inequalities between New Zealand European and Māori/Pacific smokers in New Zealand. However they also suggest that the effects may be limited in isolation. Overall, price, nicotine reduction and electronic cigarette availability are likely to provide the greatest behavioural change when combined into a comprehensive nicotine and tobacco control policy that uses price differentials to encourage transitions to less harmful products, and uses the combination of nicotine reduction and electronic cigarettes to break the link between the reinforcing effects of nicotine and combustible cigarettes.

## LIST OF FIGURES

Figure 1.	Mean change in cigarettes per day at Waves 1, 2 and 3 for NZ European and Māori/Pacific groups, plotted separately for males and females.	66
Figure 2.	Mean change in total scores for Fagerström Test of Nicotine Dependence (FTND), Glover-Nilsson Smoking Behaviour Questionnaire (GNSBQ) and Autonomy Over Smoking Scale (AUTOS) at Waves 1 and 2 for NZ European and Māori/Pacific groups, plotted separately for males and females.	68
Figure 3.	Mean change in Autonomy Over Smoking (AUTOS) subscale scores: Withdrawal Symptoms, Psychological Dependence and Cue-Induced Craving at Waves 1 and 2 for NZ European and Māori/Pacific groups, plotted separately for males and females.	70
Figure 4.	Mean predicted cigarettes per day using the CPT plotted separately for Māori/Pacific males and females and NZ/European/Other male and females.	87
Figure 5.	Simulated demand for tobacco cigarettes at prices of NZ\$0.35, NZ\$0.70 and NZ\$1.40/cigarette with e-cigarettes (NECs) at a constant price (NZ\$0.25). The left panel shows intentions to purchase tobacco cigarettes with NECs unavailable and when NECs were available, separately shown for Māori/Pacific and NZ European/Other. The right panel shows intentions to purchase NECs (at \$0.25/cigarette = 15 puffs) when they were available with regular cigarettes separately for Māori/Pacific and NZ European/Other.	90
Figure 6.	Average satisfaction ratings for regular cigarettes and e-cigarettes, shown separately for Māori/Pacific and NZ European/Other.	92
Figure 7.	Mean ratings of own brand cigarettes and Very Low Nicotine Content (VLNC) cigarettes on the four mCEQ subscales: Satisfaction, Psychological Reward, Aversion, and Craving Reduction.	109
Figure 8.	Simulated demand for own brand cigarettes and VLNC cigarettes using the CPT plotted on logarithmic axes.	111

Figure 9.	Simulated demand for Very Low Nicotine Content (VLNC) cigarettes and regular cigarettes at three increasing prices of regular cigarette while VLNC cigarettes are available at a constant, discounted price.	115
Figure 10.	Scores on Modified Cigarette Evaluation Questionnaire (mCEQ) shown separately for four different nicotine content e-liquids (0mg, 6mg, 12mg, 18mg).	133
Figure 11.	Scores on 10-point VAS for common adverse effects shown separately for four different nicotine content e-liquids (0mg, 6mg, 12mg, 18mg).	134
Figure 12.	Average simulated demand for regular cigarettes and e-cigarettes with varying nicotine content cartridges using the CPT plotted on logarithmic axes. Solid lines indicate fits of the modified exponentiated model to demand for regular cigarettes; dashed lines indicate fits to average e-cigarette demand.	136
Figure 13.	Average cigarettes per day estimated for 0mg, 6mg, 12mg and 18mg nicotine e-cigarette cartridges at prices from NZ\$0.40 to NZ\$2.00 per cigarette on the CPT.	136
Figure 14.	Average cigarettes per day and vapes per day shown separately by cartridge nicotine content and trial order. Baseline cigarettes per day is shown separately.	161
Figure 15.	Average mCEQ subscale scores after a two week trial period for 0, 6, 12 and 18mg nicotine content cartridges. Satisfaction, Psychological Reward, Aversion and Craving Reduction are shown separately.	162

## LIST OF TABLES

Table 1.	Demographic and smoking dependence information for Māori/Pacific and NZ European/Other groups.	64
Table 2.	Mean scores for measures of demand derived from the CPT.	88
Table 3.	Participants characteristics ( <i>N</i> =40)	107
Table 4.	Mean scores and correlation coefficients for measures of demand derived directly from the CPT and from fits of Koffarnus et al.'s (2015) exponentiated model shown separately for own brand and VLNC cigarettes.	113
Table 5.	Participant characteristics ( <i>N</i> =46)	132
Table 6.	Participant characteristics ( <i>N</i> =35)	158
Table 7.	Correlations coefficients for mCEQ subscales for 0, 6, 12 and 18mg e-cigarette cartridges after first-time experience in the laboratory and after two weeks experience in the field trial.	163

## LIST OF SUPPLEMENTARY MATERIAL

Chapter 5	Supplementary Material 1.	121
	Table S1. Correlations between dependence measures, mCEQ subscale scores and derived demand measures shown separately for regular and VLNC cigarettes	
Chapter 6	Supplementary Material 1.	142
	Cigarette Purchase Task and Cross-Price Task Information	
Chapter 6	Supplementary Material 2.	144
	Table S2. Mean scores and correlation coefficients for measures of demand derived directly from the CPT and from fits of Koffarnus et al.'s (2015) exponentiated model shown separately for 0mg, 6mg, 12mg and 18mg e-cigarette cartridges and regular cigarettes.	
Chapter 6	Supplementary Material 3.	147
	Table S3. Correlations for Essential Value and Cross-Price Elasticity with smoking habit (cigarettes smoked per day) and dependence (Fagerström Test of Nicotine Dependence, FTND; Glover-Nilsson Smoking Behaviour Questionnaire, GNSBQ), and subjective effects (mCEQ subscales) for 0mg ,6mg, 12mg and 18mg e-cigarette cartridges	

## 1. INTRODUCTION

### 1.1 Background

As one of the leading causes of premature death worldwide, tobacco smoking is considered a global epidemic (World Health Organization, 2011, 2013). Many countries have implemented comprehensive tobacco control programmes aimed at reducing smoking prevalence and improving public health. An important part of these programmes are population-level strategies, many of which are supported by the World Health Organization due to strong empirical support and efficiency at reaching many people (King, Pechacek, & Mariolis, 2014; World Health Organization, 2005). Though smoking prevalence has been declining in developed countries for several decades; smoking continues to be the leading cause of preventable premature death (World Health Organization, 2011, 2013). There has been increasing interest in ‘endgame strategies’; aimed to reduce smoking to minimal levels ( $\leq 5\%$ ) by specific timeframes. These have been established in New Zealand (New Zealand Government, 2010, 2016), Scotland (The Scottish Government, 2013), Ireland (Department of Health, 2013), Finland (Ministry of Social Affairs and Health, 2014) and multiple Pacific Island states (World Health Organization Western Pacific Region, 2011).

New Zealand has had a comprehensive tobacco control programme since 1985, which includes a range of strategies including smokefree environments, an increasing range of cessation support, public health programs, and tobacco excise tax. In 2010 the New Zealand Government supported the aspirational goal to become a smokefree nation (defined as  $< 5\%$  smoking prevalence for all population groups) by the year 2025 (Smokefree 2025) (Māori Affairs Committee, 2010; New Zealand Government, 2010, 2016). In addition to achieving a smokefree population, in recent years there has been increasing emphasis on reducing inequalities in smoking-related health outcomes. Smoking is a major contributor to inequalities in health outcomes observed between ethnic groups in New Zealand, notably the consistently poorer outcomes for Māori and Pacific Island people (Blakely, Ajwani, Robson,

Tobias, & Bonne, 2004; Howden-Chapman & Tobias, 2000; Wamala, Blakely, & Atkinson, 2006). Smoking prevalence among Māori (35.5%) and Pacific Island groups (22.8%) is elevated compared to New Zealanders of European descent (NZ European) (12.5%) (Ministry of Health, 2016) and is a major contributor to the poorer health outcomes for these groups (Ministry of Health, 2001).

Raising the price of cigarettes through tobacco excise tax policy is internationally supported as the most effective single tobacco control strategy and is a fundamental part of any comprehensive tobacco control program (Chaloupka, Straif, & Leon, 2011; Chaloupka, Yurekli, & Fong, 2012; Dunlop, Perez, & Cotter, 2011; Gallet & List, 2003; Gallus, Schiaffino, La Vecchia, Townsend, & Fernandez, 2006; Hanewinkel & Insensee, 2006). Economic research provides a substantial evidence base that cigarette smoking is sensitive to price, and suggests that overall, a price increase of 10% would reduce demand for cigarettes by approximately 4% for the general adult population in high-income countries (Gallet & List, 2003; Jha & Chaloupka, 1999). Excise tax policy is a fundamental part of New Zealand's comprehensive tobacco control programme, with annual 10% excise tax increases implemented in New Zealand since 2010 and proposed until at least 2020 (New Zealand Government, 2016). However, modelling studies suggest that existing strategies may not help achieve the Smokefree 2025 goal, particularly for priority population groups in New Zealand, including Māori and Pacific Island peoples (Cobiac, Ikeda, Nghiem, Blakely, & Wilson, 2015; Ikeda, Cobiac, Wilson, Carter, & Blakely, 2013; van der Deen, Ikeda, Cobiac, Wilson, & Blakely, 2014).

In order to reach the Smokefree 2025 goal, novel strategies are needed (Cobiac et al., 2015; Ikeda et al., 2013; van der Deen et al., 2014). It is therefore important to consider other strategies that may operate alongside excise tax policy to reduce demand for cigarettes, such as the availability of alternative products that could potentially be a substitute for cigarette



smoking. If alternative products can function as substitutes, they may create larger decreases in demand for cigarettes and ultimately reduce smoking prevalence. Two such products that could potentially function as substitutes for cigarettes are Very Low Nicotine Content (VLNC) cigarettes and electronic cigarettes (e-cigarettes). Although these are not yet fully legal for sale in New Zealand, recent proposed policy revisions (Ministry of Health, 2017) may provide a unique opportunity for New Zealand to develop a comprehensive and integrated nicotine and tobacco policy incorporating these products, which has the support of tobacco control advocates and public health professionals both in New Zealand and overseas (Donny, Walker, Hatsukami, & Bullen, 2016; Laugesen, Glover, Fraser, McCormick, & Scott, 2010).

## **1.2 Thesis Overview**

Tobacco control is a multidisciplinary field informed by theory and research from fields including medicine, public health, economics, and psychology. The research in this thesis uses a psychological approach to study potential tobacco control policies, primarily based on behavioural economics and the psychology of addiction. The aim of this thesis is to use a behavioural economic approach to understand how tobacco control strategies, such as tax policy and alternative products, may contribute to a comprehensive and integrated nicotine and tobacco policy. Chapter Two is a literature review that covers background research for the present thesis, including behavioural economic models of nicotine dependence, behavioural economic approaches to excise tax and alternative products, and the application of these approaches to priority populations in New Zealand. This is followed by five empirical chapters which are written as published or submitted manuscripts with brief prefaces to link the manuscripts, and a General Discussion.

Study 1 examined changes to smoking habits and addiction in a sample of Māori, Pacific Island, and New Zealand European smokers following two annual tobacco excise tax

increases in New Zealand. Due to the elevated smoking prevalence of Māori and Pacific Island peoples in New Zealand, it is important to understand whether tobacco excise taxes are helping to reduce smoking behaviour and prevalence in all population groups thus reducing tobacco-related health inequality, which is a part of the Smokefree 2025 goal. This manuscript was published in the Australian and New Zealand Journal of Public Health (Tucker, Kivell, Laugesen, & Grace, 2016a).

Study 2 used a hypothetical purchase task to assess simulated demand and favourability for regular cigarettes and e-cigarettes, in a sample of Māori, Pacific Island, and New Zealand European smokers after a brief single exposure to e-cigarettes. Using a hypothetical purchase task enabled the examination of demand at a broader range of prices than can be observed in the natural economy, which may provide an indication of the effects of future or larger price increases. This is particularly important due to the planned annual excise tax increases, scheduled until 2020, and the scale of the price increases anticipated. Additionally, the availability of alternative products that are attractive for Māori and Pacific Island smokers may help reduce demand for tobacco cigarettes and help reduce smoking-related inequalities. This manuscript has been published in the New Zealand Journal of Psychology (Tucker, Kivell, Laugesen, & Grace, 2017).

Studies 3 and 4 aimed to use more comprehensive hypothetical purchase tasks and self-reported subjective effects questionnaires to examine smokers' responses to a brief, single exposure to alternative products. Study 3 used these methods to compare subjective effects and simulated demand for VLNC cigarettes and regular cigarettes. Although VLNC cigarettes have no direct health benefits compared to regular cigarettes, they contain approximately 95% less nicotine. If they are found to be substitutable for regular cigarettes their availability may mean that smokers can reduce their nicotine intake and thus

dependence, making it easier for them to quit smoking. The manuscript was published in *Nicotine & Tobacco Research* (Tucker, Laugesen, & Grace, 2017).

Study 4 used the same measures to compare subjective effects and simulated demand for e-cigarettes of four different nicotine contents (0mg, 6mg, 12mg and 18mg), quantified the relationships between nicotine and various measures, and modelled demand for e-cigarettes using a combination of subjective effects measures. While the research on the long-term health implications of e-cigarettes is limited by their novelty, they are often referred to as a safer source of nicotine relative to regular cigarettes (Farsalinos & Polosa, 2014; Hajek, 2014; Hajek, Etter, Benowitz, Eissenberg, & McRobbie, 2014). If they are found to be substitutable for regular cigarettes, smokers may use e-cigarettes to reduce or quit smoking. It is currently illegal to sell nicotine-containing e-cigarettes in New Zealand; however the Ministry of Health have recently proposed changes to legislation that would allow nicotine-containing e-cigarettes to be sold as consumer products, albeit with some restrictions (Ministry of Health, 2017). As such it is important to understand the role of nicotine in smokers' initial responses to e-cigarettes and whether this affects hypothetical demand for the products. This study was submitted to *Addictive Behaviors* (Tucker, Bullen, Laugesen, & Grace, 2017a).

Study 5 follows on from Study 4 by examining the stability of participants' ratings of subjective effects of e-cigarettes following their first exposure, and after two weeks of use. This study tests combinations of subjective effects ratings as predictors of e-cigarette uptake. This is important as previous research on subjective effects and simulated demand was conducted only after a single, brief exposure, and it is important to understand whether this corresponds with longer-term ratings and actual smoking behaviour. This study has been submitted to *Nicotine & Tobacco Control* (Tucker, Bullen, Laugesen, & Grace., 2017b).

Finally a General Discussion integrates the empirical work and draws connection with published literature, applications to New Zealand, and directions for the future with regard to regulation of alternative products in a comprehensive tobacco control programme, in the context of a smokefree goal.

## 2. LITERATURE REVIEW

This chapter outlines behavioural economic approaches to tobacco control, specifically as applied to the strategies examined in this thesis: price policy and availability of alternative products. The literature review begins by detailing the concept of nicotine dependence and the most common models, before describing behavioural economic models of nicotine dependence and smoking behaviour. The following subsection will describe research applying behavioural economic concepts and methodologies to tobacco price and the effect of alternative products on demand for cigarettes. With regard to alternative products, this chapter will focus on consumer response to specific novel products (VLNC cigarettes and e-cigarettes) and how this response is likely to relate to future behaviour. Throughout the chapter, particular attention will be paid to the application of these concepts to priority groups in New Zealand, and how the research may inform public health policy. The chapter will conclude with a summary of the major themes, the overall goals of the thesis, and an outline of how the subsequent empirical chapters add to the evidence base and may inform policy.

### 2.1 Nicotine Dependence

Although the toxicity of smoking is related primarily to other components of smoking, the pharmacological effects of nicotine primarily produce addiction to tobacco (Benowitz, 2008; Stolerman & Jarvis, 1995; US Centre for Health Promotion and Education, 1988). As is common in the literature, throughout this thesis the terms ‘addiction’ and ‘dependence’ will be used interchangeably as they describe similar processes that sustain drug use and both implicate a loss of control over drug-taking behaviour (Benowitz, 2008, 2010). Most definitions of drug dependence and/or addiction are consistent with the World Health Organization (WHO) definition of drug dependence as “a behavioural pattern in which the use of a given psychoactive drug is given a sharply higher priority over other behaviours which once had a significantly higher value” (Edwards, Arif, & Hodgson, 1981,

p.229) . A wealth of evidence supports the idea that nicotine is a powerful drug of addiction based on the intractability of the smoking habit, low rates of success in cessation attempts, development of tolerance and sensitization, a well-defined nicotine withdrawal syndrome, and the efficacy of nicotine replacement therapy (NRT) for smoking cessation (Stolerman & Jarvis, 1995). Nicotine dependence is a complex process comprised of biological, psychological, behavioural and cultural factors, which interact to produce repetitive and compulsive use of tobacco (Heishman, 1999).

Most theories of nicotine dependence are based on a bio-behavioural mechanism in which nicotine functions as a reinforcer and repetitive tobacco use is a learned behaviour. Inhaled nicotine from cigarettes is rapidly absorbed through the lungs, enters circulation and reaches the brain within seconds (Benowitz, 2010). The efficiency of absorption and the high amounts of nicotine that reach the brain play a fundamental role in promoting and sustaining nicotine addiction (Henningfield & Keenan, 1993). Once in the brain, nicotine stimulates nicotinic cholinergic receptors which release a variety of neurotransmitters including dopamine, which is associated with pleasure and approach behaviour and is thought to be primarily responsible for the positively reinforcing effects that promote continued nicotine use (Di Chiara, 2000). Repeated nicotine intake and increased activity on nicotinic cholinergic receptors leads to desensitization (closure and unresponsiveness) and upregulation (an increase in the number of binding sites) of these receptors (Benowitz, 1999; Benwell, Balfour, & Birrell, 1995; Pidoplichko, DeBiasi, Williams, & Dani, 1997), leading to tolerance and thus dependence. Craving and withdrawal symptoms, including negative affect, restlessness, difficulty concentrating, insomnia, decreased heart rate and increased appetite (American Psychiatric Association, 1994), occur when desensitized receptors become unoccupied during abstinence, and these symptoms are alleviated with subsequent nicotine binding (Dani & Heinemann, 1996; Wang & Sun, 2005). As a result, smokers are more likely

to continue nicotine intake to maintain receptors in a sensitized state to avoid withdrawal in a process of negative reinforcement (Benowitz, 2008; Brody et al., 2006; Tiffany, Conklin, Shiffman, & Clayton, 2004).

These mechanisms assume that nicotine acts as a primary reinforcer and its immediate pharmacological effects motivate continued use to modulate arousal, mood and performance (Corrigall & Coen, 1989; Henningfield & Goldberg, 1983; Tiffany et al., 2004). In addition to the direct reinforcing properties of nicotine, non-nicotine components of tobacco smoking have been shown to have a critical influence on persistent smoking. As a consequence of classical conditioning, the previously neutral stimuli associated with nicotine develop into conditioned reinforcers after repeated pairing with nicotine (Palmatier et al., 2007). In this way, additional sensorimotor (sight, smell and taste of smoke; sensations in the mouth and throat; handling or manipulating cigarettes) and contextual stimuli (certain locations, times of day, activities, or people associated with smoking) may become important determinants of cigarette smoking.

**2.1.1. A behavioural economic perspective.** Behavioural economics expands on bio-behavioural models of nicotine dependence by applying economic principles to psychological models of nicotine addiction. Behavioural theories assume that smoking behaviour is determined primarily by the magnitude of the reinforcer and the effects of conditioning; behavioural economic theory also takes into account the response requirement or cost, thus including the economic context in which cigarettes are available (Glautier, 2004). This field encompasses several economic perspectives; however in this thesis it specifically refers to consumer demand theory and is primarily concerned with how demand for a commodity, such as tobacco, varies as a function of price (Bentzley, Fender, & Aston-Jones, 2013; Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988). This approach can be applied to the study of smoking in two ways: 1) to explore the responsiveness of smokers to

price policies, thus informing policymakers about the most effective ways in which to use tax and price policy to reduce tobacco cigarette smoking, and 2) to examine the introduction of novel tobacco-related products into the market and the impact these products may have on demand for tobacco. In contrast to econometric approaches which study the impact of these policies at an economy-wide level, a behavioural economic approach applies quantitative demand models such as the exponential (Hursh & Silberberg, 2008) and modified exponentiated model (Koffarnus, Franck, Stein, & Bickel, 2015) to individual purchasing and hypothetical purchasing behaviour.

## **2.2 Price Policy**

Despite the above mentioned reinforcing properties of smoking, it has long been accepted that increases in the price of cigarettes are associated with reductions in smoking prevalence (Chaloupka & Warner, 2000; Chaloupka et al., 2012; IARC Working Group, 2011). Tobacco excise taxes are a widely-used tobacco control strategy due to their dual effects of reducing tobacco use and generating revenue, typically at low administrative cost (Chaloupka & Warner, 2000). This strategy is theoretically based on a fundamental concept in economics known as the law of demand, referring to the negative relationship between the price of a product and the quantity demanded (Lewis, 2008). Increasing prices encourages smokers to quit or reduce consumption and discourages non-smokers from starting, leading to an overall decline in consumption (Contreary et al., 2015). Studies that project health gains based on econometric estimates of demand and studies on the health consequences of smoking indicate that hundreds of thousands of premature deaths could be avoided through large increases in tobacco taxes (General Accounting Office, 1989; Harriss, 1987; Levy, Benjakul, Ross, & Ritthiphakdee, 2008; Levy, Cummings, & Hyland, 2000; Levy, Ross, Zaloshnja, Shuperka, & Rusta, 2008; Ranson, Jha, Chaloupka, & Nguyen, 2002; Warner,



1986). Accordingly, tobacco taxes are widely viewed as a powerful public health policy tool (Chaloupka & Warner, 2000).

The strength of the inverse relationship between price and consumption is quantified as price elasticity of demand: the percentage change demand due to a percentage change in price (Lewis, 2008). For example the mean price elasticity of demand estimated from a meta-analysis is -0.4, which indicates that a 10% increase in the price of tobacco cigarettes would be predicted to reduce consumption by 4% (Gallet & List, 2003). The use of price elasticity estimates and their normalisation in percentage terms is useful for judging the utility of research findings for informing policy in terms of feasibility and intended consequences. There are many price elasticity estimates for cigarettes published from a range of different sources of data, specifications and research designs.

**2.2.1 Economic studies of price policy.** Price elasticity estimates are traditionally generated from econometric studies using aggregate data and household/individual level survey data. Aggregate data is usually country- or state-level time-series data published at regular intervals where the dependent variable is the quantity of cigarettes consumed. However, since this cannot be directly observed it is proxied by a measure which represents tax paid production or shipments. These strategies are limited as they cannot provide estimates of the impact of price changes in different groups (e.g. gender, race, income or age) or whether consumption decreased due to cessation or smoking reduction (IARC Working Group, 2011). Longitudinal household/individual level survey data sets can answer a broader range of questions than aggregate data. However, several challenges remain including accurately measuring price (which may vary even within a limited geographical area) (Cawley & Ruhn, 2012), potential self-reporting biases (Gallus et al., 2011; Warner, 1978) and omitted macro-level variables (such as advertising, availability of other products and social acceptability) (IARC Working Group, 2011). Nonetheless, the proportion of demand

studies using aggregate data has declined relative to studies using household or individual level data, likely due to the increased range of hypotheses that may be tested with these data, especially given increasing interest in targeting high priority groups such as youth, low-income groups and ethnic minority groups.

Both aggregate and household/individual level studies comprise a substantial body of research and are documented in a number of narrative reviews (Chaloupka et al., 2011; Chaloupka & Warner, 2000; IARC Working Group, 2011) and one meta-analysis to date (Gallet & List, 2003). Studies from high-income countries indicate that price elasticity of demand for cigarettes ranges from -0.25 to -0.5, with most clustered around -0.4 (Chaloupka & Warner, 2000; Chaloupka et al., 2012; Gallet & List, 2003; IARC Working Group, 2011). As stated previously, this indicates that a 10% increase in the price of tobacco cigarettes would be predicted to reduce consumption by 4%. Gallet and List (2003) conducted a meta-analysis synthesising 523 elasticity estimates of cigarette demand from 86 studies published between 1955 and 2001 and found a mean overall price elasticity of demand of -0.48 for cigarettes, with a large standard deviation [0.43]. They found that elasticity of demand for cigarettes was larger in the long run (after a period of time to respond to a price change) [-0.44] than the short run (i.e. immediately following a change in price) [-0.4]; larger for men [-0.5] than women [-0.34]; and larger for teens [-1.43] and young adults [-0.76] than for adults [-0.32]. It was also found that the cigarette price elasticity estimates were not affected by many aspects of the empirical model or specification used, for example whether addiction was accounted for in the model, or whether time-series or cross-sectional data were used (U.S. Department of Health, 1964). This suggests that the estimation methods used do not have a significant impact on the estimates of price elasticity of demand for cigarettes. The meta-analysis suggests that, based on studies published before 2001, demand for cigarettes is

relatively inelastic but somewhat responsive to price. Similar elasticity estimates have been found in studies in developed countries published since 2001 (Gallus et al., 2006).

**2.2.1.1 Economic studies in New Zealand.** In New Zealand, excise tax was applied to tobacco in the 1980s, 1990s and in 2000, and legislation for a series of scheduled, annual excise tax increases from 2010-2020 were passed in the Customs and Excise (Tobacco Products – Budget Measures) Amendment Act 2012 and 2016 (New Zealand Government, 2016). These efforts have provided opportunities to examine smoking-related responses to tax increases. Two studies used aggregate data to estimate price elasticity of demand for tobacco in New Zealand. They both estimated price elasticity of demand at around -0.45 (O'Dea, Thomson, Edwards, & Gifford, 2007; Thomson, O'Dea, Wilson, Reid, & Howden-Chapman, 2000); similar to international estimates (Gallet & List, 2003). However, it must be noted that multicollinearity is likely to pose a problem in this data. Due to correlations between increasing cigarette prices and the implementation of other social changes in New Zealand (e.g. smokefree environments and changes in social attitudes), the effects of price cannot be completely separated from the effects of other social policies (O'Dea et al., 2007).

Considerable cross-sectional evidence suggests that smokers experienced increased pressure to quit after excise tax increases in NZ. The volume of calls on a national smoking cessation support phone line in May 2010, following an excise tax increase, exceeded those in May 2008 and 2009 (Salmon & Ball, 2010) and both telephone and face-to-face surveys suggest that there was a significant increase in the amount of smokers' making quit attempts or smoking-related changes (Cowie, Glover, & Gentles, 2014; Grace, Kivell, & Laugesen, 2014; MacFarlane, Paynter, Arroll, & Youdan, 2011; Walton, Li, Newcombe, Tu, & Berentson-Shaw, 2013). These studies support the effectiveness of tobacco excise tax increases as a strategy to promote smoking reduction and cessation, and ultimately reduce smoking prevalence.

However, there are concerns about whether these changes in behaviour are seen in all population groups, including Māori and Pacific Island peoples, who are economically disadvantaged compared to New Zealanders of European descent (Salmond, Crampton, Atkinson, & Edwards, 2012). Some research suggests that excise taxes may be more effective at achieving reductions in smoking for economically disadvantaged and minority groups in the US (Chaloupka & Pacula, 1999; Farrelly, Bray, Pechacek, & Woollery, 2001; Gruber & Zinman, 2001; Tauras, 2007), which suggests that more changes in behaviour may be seen for Māori and Pacific Island smokers than for New Zealand European smokers. However, there is evidence that smoking prevalence among Māori and Pacific Island groups remains high (Ministry of Health, 2014d; Salmond et al., 2012). Hill, Blakely, Fawcett, and Howden-Chapman (2005) examined reductions in smoking prevalence between 1981 and 1996 and found that these were primarily driven by a decrease in smoking among high socioeconomic groups and the non-Māori and non-Pacific Island population. Similarly, Salmond et al. (2012) studied reductions in smoking prevalence between 1996 and 2006 and concluded that Māori continue to have an “exceedingly high prevalence of smoking despite a policy focus on reducing disparities in smoking” (p.668). Though these studies do not specifically assess the effect of tobacco excise tax, they used survey data spanning periods where tobacco excise taxes were implemented along with other policies, which suggest that these policies may not be effective in reducing smoking inequalities. It is also important to note that these studies examine smoking prevalence, which would be driven by reductions in smoking uptake and increases in smoking cessation. They do not assess other changes in smoking behaviour that may be associated with later cessation such as reducing cigarettes per day (Begh, Lindson-Hawley, & Aveyard, 2015; Hughes & Carpenter, 2006; Hyland et al., 2005; Klemperer & Hughes, 2016). Studies that compare these responses between different population groups report mixed results. Some have reported significantly greater reductions in cigarettes per day

in Māori and Pacific Island groups following tax increases (Grace et al., 2014) while others have reported greater reductions in New Zealand European groups (Walton et al., 2013). It is important to clarify how Māori and Pacific Island smokers respond to increases in the price of cigarettes due to their elevated smoking prevalence and poor smoking-related health outcomes.

It is important to evaluate the effectiveness of the currently scheduled excise tax increases, both in general and for priority groups, for achieving New Zealand's Smokefree 2025 goal. Dynamic modelling procedures have used aggregate data to forecast future trends in smoking with different scenarios of various excise tax rates (Cobiac et al., 2015; Ikeda et al., 2013; van der Deen et al., 2014). Ikeda et al. (2013) projected current trends from the 1992-93 and 2011-12 New Zealand Health Survey and the 1996 and 2006 census to model smoking prevalence in 2025 using a business as usual (BAU) scenario. They estimated smoking prevalence of 11% and 9% for non-Māori males and females respectively, and 30% and 37% for Māori males and females respectively. van der Deen et al. (2014) replicated this study when the 2013 census became available, which reported lower than expected smoking prevalence, especially for Māori (Statistics New Zealand, 2014b). With this new data, they estimated smoking prevalence of 8.3% and 6.4% for non-Māori males and females respectively, and 18.7% and 19.3% for Māori males and females respectively. These projections are more encouraging for achieving the Smokefree 2025 goal but  $\leq 5\%$  prevalence was still not predicted by any demographic group and large inequalities in smoking prevalence remained. Cobiac et al. (2015) modelled 2025 smoking prevalence under a number of different scenarios: 0%, 5%, 10%, 15% and 20% annual tobacco excise tax increases. They found that the current approach (scheduled annual tobacco excise tax increases of 10%) would not achieve  $\leq 5\%$  smoking prevalence by 2025 [projected prevalence = 8.7%] and that even substantially higher increases of 20% would fall short [projected

prevalence = 7.6%]. Overall, these simulation studies conclude that existing taxation strategies must be intensified and implemented alongside more intensive or novel strategies in order for a tobacco endgame to be feasible.

**2.2.2. Behavioural economic studies of price policy.** Using an experimental approach, behavioural economics has the advantage of generating price and consumption data at a broader range than can be assessed in the natural economy, and allows for the examination of potential changes in price before they are implemented at a population level. Demand or consumption data may be obtained via a range of experimental designs from traditional self-administration studies measuring changes in actual behaviour to the more recent development of hypothetical purchase tasks measuring self-report estimates of behaviour. These will be discussed in the following subsection.

Human self-administration studies typically involve adult smokers participating in laboratory sessions in which they must pay a broadly defined price, which traditionally involves an effort such as plunger pulls for a pre-set number of puffs on a cigarette. This approach uses a broad definition of price including monetary cost, effort and time required to obtain cigarettes thus allows for a range of different experimental designs. In these designs plunger pulls may be directly exchanged for a specified number of puffs on a cigarette (Bickel, Degrandpre, Hughes, & Higgins, 1991b) or for money which could then be spent on cigarettes (Degrandpre & Bickel, 1995). Different definitions of price can be standardised through the use of unit price; a cost-benefit ratio in which cost (broadly defined) is divided by the unit of the commodity (Bickel, Marsch, & Carroll, 2000). Reinforcers are generally delivered on progressive ratio schedules where the number of responses required systematically increases within or between sessions until a breakpoint is reached; where the responses or drug-seeking behaviours cease (Stafford, LeSage, & Glowa, 1998).

Estimates of demand from self-administration studies are generally consistent with econometric studies (Chaloupka & Warner, 2000). An inverse relationship between cigarette smoking and price has been consistently demonstrated (Bickel & Degrandpre, 1996; Bickel, Degrandpre, Higgins, Hughes, & Badger, 1995; Bickel et al., 1991b; Bickel & Madden, 1999; Degrandpre, Bickel, Higgins, & Hughes, 1994; Degrandpre, Bickel, Hughes, & Higgins, 1992; Johnson & Bickel, 2006) and price elasticity estimates from behavioural economic experiments generally range from  $-.16$  to  $-.41$  (Bickel, Degrandpre, & Higgins, 1995; Degrandpre et al., 1994), which is similar to those generated in econometric studies [ranging from  $-.25$  to  $-.5$ ] (Chaloupka & Warner, 2000; Chaloupka et al., 2012; Gallet & List, 2003; IARC Working Group, 2011).

Bickel and Madden (1999) suggested that self-administration procedures may be useful for examining the consequences of existing tax policies, predicting the consequences of changes of a greater magnitude than have been previously observed, and also examining other phenomena that may inform tobacco control policy. However, limitations of this approach include the inherent health risk of having participants consume potentially larger amounts of harmful substances than they ordinarily would, the lengthy sessions with rigorous participant demands in order to demonstrate stable responding at each price, and the expense due to compensation of participant time, purchasing substances and specialised equipment (Reed, Kaplan, Roma, & Hursh, 2014).

Simulated demand studies use hypothetical purchase tasks, such as the Cigarette Purchase Task (CPT) to estimate demand for a substance and account for some of the limitations of self-administration studies. Hypothetical purchase tasks are a relatively time- and cost-efficient approach to collect demand data; they ask individuals to estimate their daily cigarette consumption at a broad range of prices (MacKillop et al. 2012). The initial question typically assesses cigarette purchases at zero cost per unit (per cigarette or pack),

and subsequent questions gradually increase in price up to a level where consumption ceases or is drastically reduced. Hypothetical consumption data can be used to generate demand curves, which are a useful way of characterising the effect of price on behaviour (Hursh & Winger, 1995). Demand curves are generated by plotting consumption as a function of price, the slope of which is equivalent to price elasticity of demand (Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014). The following subsection will outline the most commonly used regression models used to fit to demand curve data.

**2.2.2.1 Demand Curve Analysis.** Demand curve analysis provides multiple unique measures of demand that can be normalised and directly compared across different experimental designs, and across reinforcers of various magnitudes, potencies and types (Bentzley et al., 2013).

**2.2.2.1.1. The exponential model.** Hursh and Silberberg (2008) proposed an exponential function that can be fitted to consumption data and used to adequately describe most demand curves when plotting the log of consumption as a function of price:

$$\log_{10}Q = \log_{10}Q_0 + k(e^{-\alpha Q_0 C} - 1)$$

$Q$  is consumption at price  $C$ ,  $Q_0$  is ‘intensity’ or consumption as price approaches zero,  $k$  is the span of the function in  $\log_{10}$  units, and  $\alpha$  is elasticity, a fitted parameter which determines how quickly demand falls as price increases (higher values of  $\alpha$  indicate that demand falls more rapidly with price). This equation has been widely used and generally describes demand data well, accounting for a high proportion of the variance of consumption data across a variety of contexts and procedures (Grace et al., 2014; Grace, Kivell, & Laugesen, 2015a; Hursh & Silberberg, 2008; Koffarnus, Hall, & Winger, 2012; Koffarnus, Wilson, & Bickel, 2015; Roma, Kaminski, Spiga, Ator, & Hursh, 2010).

However, the exponential model is limited in its management of zero consumption values (Koffarnus, Franck, et al., 2015). Fitting the exponential model requires log-



transforming consumption values. Because zero consumption values cannot be represented on a logarithmic scale, researchers have used a range of approaches to manage zero consumption value including omitting zeroes from analyses (Koffarnus et al., 2012), replacing them with small values [0.1 or 0.01] (Galuska, Banna, Willse, Yahyavi-Firouz-Abadi, & See, 2011; Grace et al., 2014, 2015a; MacKillop et al., 2012) or only using group fits of the model as opposed to individual fits (Koffarnus, Wilson, et al., 2015). However, these solutions are not ideal because they exclude, or impose significant manipulation of, legitimate data (Koffarnus, Franck, et al., 2015).

*2.2.2.1.2 The modified exponentiated model.* Koffarnus, Franck, et al. (2015) proposed a modified exponentiated version of Hursh and Silberberg's (2008) model of demand to avoid the problem of omitting or replacing zero consumption values where both sides are raised to the power of 10, allowing untransformed consumption values to be fitted:

$$Q = Q_0 * 10^{k(e^{-\alpha Q_0 C} - 1)}$$

Koffarnus, Franck, et al. (2015) compared the modified exponentiated model with the exponential model using empirical and simulated data. They found that the modified exponentiated model provided a better fit for the data, was able to fit all consumption values including zeroes, and more accurately reproduced the parameters used to generate the simulated demand data. The equation has subsequently shown good model fits for demand data obtained from a cigarette purchase task (O'Connor et al., 2016) and alcohol purchase task (Snider, LaConte, & Bickel, 2016).

*2.2.2.1.3. Metrics from demand curve analysis.* A number of additional metrics can be derived from fits of the exponential model or the modified exponentiated model to the demand curve. As mentioned previously,  $Q_0$  is consumption as price reaches zero and is considered a measure of intensity of demand.  $Q_0$  can be directly observed as consumption when a reinforcer is freely available, for example at \$0 or zero responses required, or it can

be derived as a fitted parameter.  $\alpha$  is a fitted parameter that determines how quickly demand falls as price increases.  $\alpha$  is inversely proportional to Essential Value (EV), a definition of the value of a reinforcer which is scaled according to the span of consumption data in the experiment ( $k$ ) thus allowing EV to be compared across different studies and reinforcers (Hursh & Roma, 2016):

$$EV = 1/(100 * \alpha * k^{1.5})$$

$P_{max}$  is the price at which maximum response output is elicited (e.g. money spent or responses) and can be considered the price at which demand shifts from inelastic to elastic (Hursh, 1991). At prices lower than  $P_{max}$  consumption would be relatively stable and similar to  $Q_0$ , but at prices higher than  $P_{max}$  consumption falls more rapidly with increasing price. A range of formulas have been used to approximate  $P_{max}$  (Hursh & Roma, 2013; Hursh & Winger, 1995), but now the most widely used formula is a normalised equation which allows for analysis across a continuous range of prices beyond those used in any individual study. This approach expresses consumption as a percentage of maximal consumption ( $Q_0=100\%$ ) and adjusts for  $k$ :

$$P_{max} = m/(Q_0 * \alpha * k^{1.5}) \text{ where}$$

$$m = 0.084k + 0.65$$

$O_{max}$  is the corresponding maximum response output at  $P_{max}$  and is directly proportional to  $P_{max}$  (Hursh & Winger, 1995). Breakpoint (BP) is the price at which consumption reduces to zero, thus the price at which smokers would quit.

**2.2.2.2. Purchase task studies.** Studies suggest that consumption data generated from hypothetical purchase tasks generates demand curves which conform to the exponential model of demand and are comparable to those generated in self-administration studies (Few, Acker, Murphy, & MacKillop, 2012; Grace et al., 2014, 2015a; MacKillop et al., 2008; MacKillop & Tidey, 2011). These tasks can also assess individual differences in substance

use using the demand metrics derived from demand curves (Murphy, MacKillop, Tidey, Brazil, & Colby, 2011). Demand metrics derived from the Cigarette Purchase Task (CPT) have shown robust convergent and divergent validity in adults (Chase, Mackillop, & Hogarth, 2013; Few et al., 2012; Grace et al., 2014; MacKillop et al., 2008; MacKillop & Tidey, 2011) and adolescents (Murphy et al. 2011). Studies have found significant positive correlations between derived demand metrics and smoking-related variables such as cigarettes per day and nicotine dependence, with the strongest correlations found for  $Q_0$  [ $r = .23-.68$ ] and  $O_{max}$  [ $r = .27-.88$ ], and less so for breakpoint [ $r = .02-.41$ ] (Chase et al., 2013; Grace et al., 2014; Mackillop et al., 2016; MacKillop et al., 2008; Murphy et al., 2011). Chase et al. (2013) performed a multiple regression with  $O_{max}$ ,  $Q_0$  and breakpoint and found that all three metrics significantly predicted variation in nicotine dependence;  $O_{max}$  was the strongest predictor.

A potential limitation of using hypothetical purchase tasks is their reliance on estimated, self-reported consumption, which may not correspond with actual observed behaviour (Jacobs & Bickel, 1999). However, temporal discounting studies requiring participants to choose between a delayed and immediate reward have shown that choices for hypothetical rewards correspond with choices for actual rewards (Bickel, Pitcock, Yi, & Angtuaco, 2009; Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al., 2004). Similarly, studies comparing hypothetical and actual reward conditions on an alcohol purchase task showed that there were no significant differences in performance between the two conditions, and high correlations between conditions [ $r = .87$ ] (Amlung, Acker, Stojek, Murphy, & MacKillop, 2012; Amlung & MacKillop, 2015).

Only one study has compared actual and hypothetical conditions using a CPT. Wilson, Franck, Koffarnus, and Bickel (2016) found that daily purchasing behaviour on a hypothetical cigarette purchase task was not significantly correlated with real and potentially

real weekly purchase tasks [ $r = .41-.43$ ;  $p > .05$ ]. However, it was stated that this could be due to the different time horizons used; the hypothetical purchase task asked about cigarettes per day while the real and potentially real purchase conditions required participants to purchase one week's worth of cigarettes. Additional studies using identical prices and consumption periods would be needed to confirm whether hypothetical cigarette consumption would reflect actual consumption. However in the CPT, as in alcohol purchase tasks, choices are being made for familiar goods organised in discrete and well-understood units (such as price in dollars and cigarettes either as single cigarettes or familiar, purchasable pack sizes) which should allow for accurate estimation of consumption (MacKillop et al., 2012). These studies suggest that the CPT may be a valid and reliable way to measure demand for cigarettes and the derived measures may be helpful for predicting which smokers will benefit most from tobacco excise tax increases, and which smokers may be better reached using alternative strategies.

Demand curve analysis provides a rich understanding of how changes in price would influence the decision to smoke, and the use of monetary price offers a clearer application to public policy. Purchase tasks can be useful in examining public policy issues because the same magnitude, range and density of price change cannot be examined in actuarial studies of existing market data (Hursh & Roma, 2013; MacKillop et al., 2012). Several studies have highlighted applications for public policy including predicting individual responses to excise tax increases (Grace et al., 2014) and behavioural interventions (Secades-Villa, Pericot-Valverde, & Weidberg, 2016) and left-digit price effects (MacKillop et al., 2014; MacKillop et al., 2012).

Grace et al. (2014) demonstrated the application of the CPT to public policy by establishing that CPT-derived demand indices can predict changes in smoking behaviour in response to excise tax increases. This study found that a measure of local elasticity based on

the regression slope for simulated demand at prices close to the market price of cigarettes (ranging from NZ\$0.64 to NZ\$0.85 per cigarette) predicted decreases in smoking after the tax increase. Secades-Villa et al. (2016) assessed whether CPT indices predicted treatment outcomes among smokers receiving combined cognitive behavioural therapy and contingency management. This study found that higher elasticity was associated with more days of continuous smoking abstinence after controlling for cigarettes smoked per day, years of smoking and nicotine dependence. These studies suggest that the demand indices derived from the CPT may have clinical utility and can be predictive of behaviour change (MacKillop, Miranda, et al., 2010).

MacKillop et al. (2012) used a range of 73 prices organised highly densely around current market price and identified that a major influence on price effects was left-digit bias: large magnitude effects on consumption based on the transition from one whole dollar amount to the next (e.g. \$4.80 to \$5.00 per pack). These results suggested that tax increases that traverse whole dollar pack prices would be more successful in reducing cigarette consumption. Another study found that changes in reported motivation to quit smoking at transitions across whole dollar prices per pack were approximately three times larger than changes in motivation at other price increases (MacKillop et al., 2014). This study also found that left-digit transitions had a much greater effect at market-relevant prices than at very low prices. Together, these studies highlight the importance of considering both the absolute amount and the relative position of a price increase to achieve the greatest reductions in smoking.

**2.2.3. Summary and application to New Zealand.** Price policy is internationally supported as the single most effective tobacco control strategy available and is a comprehensive part of any comprehensive tobacco control programme (Chaloupka et al., 2011; Chaloupka et al., 2012). As discussed in section 2.2.1.1., research in New Zealand also

shows support for this strategy (Cowie et al., 2014; Grace et al., 2014; MacFarlane et al., 2011; O'Dea et al., 2007; Salmon & Ball, 2010; Walton et al., 2013) and a series of scheduled, annual tobacco excise tax increases of 10% have been implemented since 2010 and are planned until 2020 (New Zealand Government, 2016). However there are some limitations. Firstly, the evidence is mixed regarding the effectiveness of tobacco excise tax policy for reducing inequalities in smoking prevalence and outcomes for Māori and Pacific Island peoples relative to the general population (Grace et al., 2014; Hill et al., 2005; Salmond et al., 2012; Walton et al., 2013). Second, simulation studies modelling smoking prevalence up to 2025 have shown that continuing to use the existing scheduled 10% tax increases will not achieve <5% smoking prevalence for any population group, and that prevalence for Māori and Pacific Island peoples will continue to be disproportionately high (Cobiac et al., 2015; Ikeda et al., 2013; van der Deen et al., 2014). Using behavioural economic methods, particularly hypothetical purchase tasks, can add to the knowledge base informing price policy by estimating demand at a broader range of prices than could be assessed in the natural economy in a time- and cost-efficient manner (Hursh & Roma, 2013; MacKillop et al., 2012). Hypothetical purchase tasks may be used to generate demand curves and derived measures of demand which provide information about price increases of greater magnitude than can currently be assessed in the natural economy, and may be compared for priority groups in New Zealand.

### **2.3. Alternative Products**

While price policy has a substantial evidence base and is a fundamental part of most comprehensive tobacco control programmes, this strategy is unlikely to achieve the substantial reductions in smoking prevalence required in countries with an endgame goal, New Zealand. A complementary strategy would be to introduce alternative, novel products to compete with regular cigarettes. Existing products include NRT products (such as nicotine

gum, patches, and lozenges), snus, and smokeless tobacco. The research in this thesis focuses on novel alternative products that may be introduced in New Zealand: e-cigarettes and VLNC cigarettes.

The commercial success of alternative products would depend on product design and characteristics that are acceptable and attractive enough to smokers to encourage them to change their behaviour. Rees et al. (2009) proposed that consumer response to a product, a result of product design and characteristics, can affect behavioural outcomes including product trial, experimentation and regular use. It is therefore important to understand aspects of consumer response in order to predict future use and to understand the relationships between factors that contribute to positive consumer responses.

Consumer response has been defined as “a set of subjective and behavioural responses which convey information, affect behaviour and likelihood of long-term product use by the consumer, and his or her future intentions for product adoption” (Rees et al., 2009, p. 3). They may include positively reinforcing factors such as taste and satisfaction, and negatively reinforcing factors including psychological reward (alleviation of withdrawal symptoms) and craving reduction. However, these factors also contribute to the abuse liability of a product (Hanson, O'Connor, & Hatsukami, 2010). Positive consumer response to novel products could encourage substitution of the novel product for regular cigarettes, however they may also indicate that the use of a product is likely to be maintained and lead to addiction, thus consumers may experience difficulty when trying to stop using the product (Hanson et al., 2010).

To contribute towards tobacco control and public health efforts, the products would need a positive consumer response, but not so positive as to perpetuate addiction to the novel product. They would also need to be safer than regular cigarettes either directly, by

reducing toxicant exposure and health risk, or indirectly by reducing nicotine dependence and promoting cessation.

**2.3.1. Measuring subjective effects.** An important and common assessment measure of alternative products are the participants' self-reported subjective experience of a product when trialled. Acute subjective effects have been measured in laboratory studies and longer-term subjective effects and patterns of use can be assessed in naturalistic environments in clinical trials. Outcome measures usually include product or sensory evaluation scales and withdrawal scales. A range of scales have been used in studies of various methodologies and for various products. Commonly used scales include the Minnesota Nicotine Withdrawal Scale (Hughes & Hatsukami, 1986), the Questionnaire of Smoking Urges (Tiffany & Drobes, 1991), and the Cigarette Evaluation Questionnaire (Westman, Levin, & Rose, 1992) or modified Cigarette Evaluation Questionnaire (Rose, Behm, Westman, & Johnson, 2000), though this list is not exhaustive and many other scales and single-item measures have been used. Although there is no consensus on the measures that best predict ongoing use of novel products, subjective effects are likely to be an important tool in determining whether a product is likely to be used and substituted for regular cigarettes. As there is no 'gold standard' measure more research is required to validate scales and key constructs, and to better understand the relationship between subjective effects and behaviour change (Hanson et al., 2010).

**2.3.2. Measuring demand.** An important feature of demand curve analysis and the derived demand measures is that they provide a standardised platform for the direct comparison of qualitatively different products. As with regular cigarettes, demand for alternative products can be evaluated using self-administration procedures or hypothetical purchase tasks (Huang, Tauras, & Chaloupka, 2014; Shahan, Bickel, Badger, & Giordano, 2001; Shahan, Bickel, Madden, & Badger, 1999; Shahan, Odum, & Bickel, 2000), however



these tasks only assess demand for each product in isolation. In reality it is likely that alternative products would be concurrently available with cigarettes and so comparative purchase tasks can be used to determine whether people would make the decision to substitute an alternative product for cigarettes. Behavioural economics provides a sophisticated but easily operationalised framework to quantify the degree and type of interactions between multiple reinforcers (Bickel et al., 2014). Not only can demand curves and derived measures be compared across different products, but the interactions between different reinforcers can be quantified using cross-price elasticity (CPE).

CPE is a measure of the relative change in demand for an alternative product available at a constant price given a change in the price of an original product. It is determined by calculating the slope of the relationship between log-transformed consumption of the alternative product and log-transformed price of the original product. There are three ways in which products can interact which lie on a continuum and can be represented by different CPE coefficients (Bickel, Degrandpre, & Higgins, 1995). If a product has a CPE coefficient of greater than zero it is considered a substitute for the original product: as the price of the original product increases and its consumption decreases, consumption of the alternative product increases. However, unless the choice is between different suppliers for the same product, most choices are between products that are not perfect substitutes (Green & Freed, 1993). Instead, alternative products are likely to be imperfect or partial substitutes with both shared and unique features. At the other end of the continuum, if an alternative product has a CPE coefficient of less than zero it functions as a complement: its consumption decreases as the price and consumption of the original product increases. Between the two extremes, an alternative product with a CPE coefficient of zero is considered independent: as the price and consumption of the original product increases, consumption of the alternative product remains unchanged. CPE coefficients can also be normalised in percentage terms to facilitate

a policy perspective. For example, a CPE coefficient of 0.15 indicated that for a 10% increase in the price of the original product, consumption of the alternative product would increase by 1.5%.

When substitutes are available, the EV of cigarettes may decline relative to when no other source of reinforcement is available (Hursh & Roma, 2016). The largest decreases in EV are likely to be when low-priced perfect substitutes are available, but even partial substitutes would produce modest declines in EV. Identifying which alternative products function as the best substitutes for conventional cigarettes may have important treatment and public health implications. Making alternatives available concurrently with conventional cigarettes but at a lower price could help drive down demand for cigarettes and make smokers more likely to stop or reduce their consumption of conventional cigarettes.

**2.3.3. Novel alternative products in New Zealand.** Understanding the behavioural economic substitutability of alternative products is especially relevant for countries that have implemented a tobacco endgame goal, such as New Zealand. The identification of effective substitutes and their introduction into the market, alongside increasing the price of tobacco, may help achieve  $\leq 5\%$  smoking prevalence. Two novel potential substitutes that have received significant attention in New Zealand and worldwide are VLNC cigarettes and nicotine-containing e-cigarettes. For a product to be considered a behavioural economic substitute, it must share a function with the original product (Green & Freed, 1993). VLNC cigarettes and e-cigarettes both share features with conventional cigarettes but operate under different mechanisms. It is important to evaluate the potential benefits of their introduction into the market.

**2.3.3.1. Very Low Nicotine Content (VLNC) cigarettes.** VLNC cigarettes, also known as reduced nicotine cigarettes or denicotinized cigarettes, contain tobacco with substantially less nicotine than regular cigarettes ( $<0.05\text{mg}$ ). Though nicotine is not the

primary cause of the detrimental health effects of tobacco, it is the primary addictive agent (U.S. Department of Health and Human Services, 2014). Thus, the reduction of nicotine in tobacco may help reduce smoking prevalence and smoking-related health outcomes in three ways: 1) reducing nicotine reinforcement and therefore dependence in current smokers and thus providing them with a greater opportunity to reduce or quit smoking, 2) reducing reinforcement in new users making them less likely to develop dependence and habitual smoking behaviour, and 3) ex-smokers who lapse are less likely to experience the positively reinforcing effects of nicotine and become regular smokers again (Donny et al., 2014). These mechanisms are primarily supported through reducing the chemical addictive potential, giving a greater possibility of behaviour change.

One concern about the introduction of VLNC cigarettes to the market is that smokers would smoke more frequently or more intensively in order to attain optimal nicotine reinforcement levels. When considering this, it is important to distinguish VLNC cigarettes from 'low yield' or 'light' cigarettes which generate lower yield of nicotine in machine testing due to features such as faster burn time or filter ventilation. Low yield cigarettes are prone to high rates of compensatory behaviours such as blocking ventilation holes, taking bigger or more frequent puffs, or smoking more cigarettes per day. Engaging in these behaviours can lead to increased toxicant exposure and smoking-related health risks (Kozlowski & O'Connor, 2002; National Cancer Institute, 2001). On the other hand, VLNC cigarettes contain substantially less nicotine in the tobacco itself (<0.05mg) yet similar satiating amounts of tar, chemical irritants and taste. This makes it extremely difficult or impossible for smokers to engage in compensatory smoking in order to obtain larger doses of nicotine (Benowitz & Henningfield, 2013; Donny et al., 2014). Studies comparing VLNC and regular cigarettes show that VLNC cigarettes are associated with low levels or complete absence of compensatory smoking based on behavioural smoking changes (e.g. cigarettes

smoked, number of puffs, puff volume), changes in biomarker exposure and cardiovascular effects (Benowitz et al., 2012; Benowitz et al., 2007; Benowitz, Jacob, & Herrera, 2006; Donny et al., 2015; Donny, Houtsmuller, & Stitzer, 2007; Donny & Jones, 2009; Hatsukami et al., 2010; Strasser, Lerman, Sanborn, Pickworth, & Feldman, 2007). As such the majority of studies support the idea that when smokers use VLNC cigarettes they do not engage in significant compensatory smoking behaviour in order to attain their usual level of nicotine.

Several studies have examined the efficacy of VLNC cigarettes for smoking cessation in clinical trials. However, the results are mixed and studies are difficult to compare due to differing methodologies, timeframes and intended use of VLNC cigarettes. Intended uses across studies include immediate switching to VLNC cigarettes from regular cigarettes, gradual nicotine reduction or “tapering”, combination with NRT, and as a pre-cessation treatment. Clinical trials have shown that immediately switching to VLNC cigarettes leads to reduced nicotine exposure, dependence and cigarettes smoked per day relative to continuing to smoke regular cigarettes after 11 days (Donny et al., 2007) and six weeks (Donny et al., 2015). Another series of studies has shown that gradual nicotine reduction or “tapering” using cigarettes with progressively lower nicotine contents (12, 8, 4, 2 and 1mg) leads to greater reductions in cigarette consumption during the study and up to 6 months follow-up compared to controls smoking their regular cigarettes (Benowitz et al., 2012; Benowitz et al., 2007; Benowitz et al., 2015). Cessation studies have shown that switching immediately to VLNC cigarettes leads to similar levels of cessation as switching to NRT (Becker, Rose, & Albino, 2008; Hatsukami et al., 2010). There is also some evidence that a combination approach of VLNC cigarettes plus NRT produces greater cessation rates and reductions in cigarette consumption than either VLNC cigarettes or NRT alone (Hatsukami, Hertsgaard, et al., 2013; Walker et al., 2012).

These studies support the view that VLNC cigarettes can reduce smoking behaviour by reducing the reinforcement properties of cigarettes and thus smoking dependence (Donny et al., 2014). However, it has been suggested that reductions in smoking could be attributed to the novel or aversive nature of the research cigarettes rather than the nicotine content per se (Donny et al., 2007). As such it is unclear whether smokers would make the decision to use VLNC cigarettes if they were not required to as part of a clinical trial. Thus it is important to also consider consumer response to VLNC cigarettes. The self-reported subjective effects (taste and satisfaction, psychological reward, and craving reduction) may provide information as to whether smokers would actually use VLNC cigarettes. This data could also be complemented by demand data from hypothetical purchase tasks and cross price tasks to inform whether individuals would purchase and use alternative products.

*2.3.3.1.1. Subjective effects.* Both clinical and laboratory studies show that smokers tend to rate VLNC cigarettes as lower quality and less satisfying than their usual brand cigarettes (Becker et al., 2008; Benowitz et al., 2006; Donny et al., 2007; Gross, Lee, & Stitzer, 1997; Strasser et al., 2007). However in some cases these effects are minimal and it has been suggested that ratings may be affected by switching from a familiar brand to a novel research cigarette and unrelated to nicotine content (Shahan et al., 1999). For example, Donny et al. (2007) found that switching from usual brand cigarettes to 0.3mg and 0.05mg cigarettes produced an immediate decrease in positive and increase in negative self-reported effects, regardless of nicotine content. On the other hand, smokers report that VLNC cigarettes reduce craving and withdrawal symptoms similarly to regular cigarettes (Donny et al., 2015; Donny et al., 2007; Gross et al., 1997), and similarly or better than some NRT products such as nicotine lozenges and patches (Donny & Jones, 2009; Hatsukami, Hertzgaard, et al., 2013; Hatsukami et al., 2010; Rezaishiraz, Hyland, Mahoney, O'Connor, &

Cummings, 2007). This suggests that despite lower favourability and minimal nicotine delivery, VLNC cigarettes may be helpful in reducing symptoms of nicotine withdrawal.

Some studies have found that the subjective effects of VLNC cigarettes are different for men and women. Barrett (2010) found that smoking a VLNC cigarette after 12 hour abstinence reduced craving in women but not men, and Vogel et al. (2014) found that women reported greater satisfaction for VLNC cigarettes in a clinical trial, while men reported greater satisfaction and suppression of withdrawal symptoms when VLNC cigarettes were combined with nicotine replacement therapy (NRT). This is supported by previous research that has found that NRT leads to greater suppression of withdrawal symptoms (Hatsukami, Skoog, Allen, & Bliss, 1995; Wetter, Fiore, Young, McClure, & de Moor, 1999) and craving (Killen, Fortmann, Newman, & Varady, 1990; Perkins et al., 2006), and higher abstinence rates (Becker et al., 2008; Perkins & Scott, 2008) in males versus females. These findings are consistent with a review which concluded that females have reduced sensitivity to nicotine reinforcement than males with less differential self-administration of nicotine versus placebo nasal spray, reduced self-reported effects of nicotine, and less response to pre-treatment with nicotine, especially at lower doses (Perkins, 2009). Studies have shown that females appear more sensitive to visual, olfactory and taste cues than males (Evans, Blank, Sams, Weaver, & Eissenberg, 2006; Perkins, Epstein, Grobe, & Fonte, 1994; Perkins et al., 2001; Perkins, Jacobs, Sanders, & Caggiula, 2002), greater behavioural dependence (Bohadana, Nilsson, Rasmussen, & Martinet, 2003), and greater importance placed on concurrently presented cues in nicotine self-administration in animal studies (Chaudhri et al., 2005; Donny et al., 2000). This potential physiological difference may account for sex differences reported in the aforementioned studies.

*2.3.3.1.2. Demand.* Only two studies have investigated demand for VLNC cigarettes. These studies used self-administration procedures with behavioural responses (plunger pulls)

as an analogue for price (Johnson, Bickel, & Kirshenbaum, 2004; Shahan et al., 1999).

Shahan et al. (1999) examined the elasticity of conventional and VLNC cigarettes using a progressive ratio schedule of reinforcement where each were available independently, before comparing preference when available concurrently. They found that when available independently, VLNC cigarettes and conventional cigarettes were similarly sensitive to price and had similar breakpoints and peak responding rates. However, when the two cigarette types were available concurrently, there was a strong preference for conventional cigarettes. This supports the theory that smoking-related stimuli can be conditioned reinforcers in the absence of the primary reinforcing properties of nicotine, but without nicotine they function as a less potent reinforcer. However, participants rated taste and smoothness lower for VLNC cigarettes, thus it is unclear to what extent preference and favourability of conventional cigarettes is due to the nicotine level or other taste and sensory differences. Johnson et al. (2004) examined the substitutability of nicotine gum and VLNC cigarettes for conventional cigarettes. By making each alternative product available at a constant unit price concurrently with conventional cigarettes at increasing unit prices, they calculated CPE for both products. They found that increasing unit price of conventional cigarettes caused an increase in consumption of nicotine gum and VLNC cigarettes in separate trials, indicating that both products act as behavioural economic substitutes for conventional cigarettes. The CPE estimates were similar for VLNC cigarettes and nicotine gum (0.20 and 0.19 respectively). However, VLNC cigarettes caused a significant reduction in conventional cigarette consumption, while nicotine gum did not. Furthermore, when both alternative products were available concurrently while conventional cigarettes increased in price, consumption of VLNC cigarettes was significantly higher than consumption of nicotine gum.

Results of these studies suggest that not only can VLNC cigarettes function as a substitute for conventional cigarettes, but that they may function as a more effective

behavioural economic substitute than nicotine gum. Although nicotine is the primary tobacco constituent that maintains dependence, VLNC cigarettes share a number of common non-nicotine features including: non-nicotine pharmacological agents; sensory features of the appearance, size and shape of the cigarette and the sight, smell and taste of smoke in the air, mouth and throat; and behaviours associated with smoking including preparatory behaviours and hand-to-mouth motor action. Over time, these features have been repeatedly paired with the self-administration of nicotine for smokers and thus may have become conditioned reinforcers and may elicit some of the reinforcing properties usually elicited from nicotine intake when administered in the absence of nicotine. This is consistent with the evidence suggesting that VLNC cigarettes tend to be rated as lower quality and less satisfying than regular cigarettes (whether due to the novel nature of research cigarettes or due to the absence of nicotine itself), but can reduce symptoms of nicotine withdrawal including craving cigarettes.

*2.3.3.1.3. Summary and application to New Zealand.* VLNC cigarettes may reduce smoking behaviour by reducing nicotine intake and thus dependence in smokers who choose to use them. VLNC cigarettes deliver minimal quantities of nicotine and thus provide reduced levels of the positively or negatively reinforcing effects of nicotine, which is likely to lead to reductions in smoking behaviour. Though they appear to reduce withdrawal symptoms at a similar rate to regular cigarettes, VLNC cigarettes are subjectively rated as less satisfying and enjoyable, suggesting their abuse liability may be lower than that of regular cigarettes. Behavioural economic studies suggest that VLNC cigarettes are partially substitutable for regular cigarettes, and it is unclear whether the properties that these products share constitute enough of a positive consumer response to encourage smokers to progress from trial or experimental use to prolonged use or actual substitution for regular cigarettes, if the two were concurrently available. Due to smokers' preferences and the partial substitutability of VLNC



cigarettes for regular cigarettes, price differentials between the two products would likely need to be maintained in order for smokers to choose to purchase VLNC cigarettes over regular cigarettes.

Another option for the use of VLNC cigarettes in tobacco control policy is a mandated nicotine reduction policy; requiring that all cigarettes must contain very low levels of nicotine. This type of population-level policy is likely to have the greatest impact on smoking behaviour by preventing concurrent use of VLNC cigarettes and regular cigarettes, which would lead to intermittent nicotine reinforcement and continuation of cigarette smoking behaviour. If VLNC cigarettes were the only combustible tobacco product available to smokers, smoking prevalence would be likely to decline more rapidly. However, there is limited behavioural economic research using VLNC cigarettes and as such little is known about demand for these products using monetary prices. Using hypothetical purchase tasks to compare demand for, and substitutability of VLNC cigarettes and regular cigarettes could inform how VLNC cigarettes may best contribute to tobacco control policy.

In New Zealand, the concept of a nicotine reduction policy is supported by the general public, researchers and public health professionals (Donny et al., 2016; Laugesen et al., 2010; Li, Bullen, Newcombe, Walker, & Walton, 2013). A population-based survey of New Zealanders found that 81% of the sample indicated that they agreed with the statement “the nicotine content of cigarettes should be reduced to very low levels so that they are less addictive”, including 63% of smokers, 73% of Māori and 87% of Pacific Island respondents (Li et al., 2013). This provides some preliminary evidence that policies using VLNC cigarettes may be accepted in New Zealand. Donny et al. (2016) highlighted the advantages of implementing and evaluating a nicotine reduction policy, potentially using VLNC cigarettes in New Zealand including: the comprehensive tobacco control programmes and support for quitting; the aspirational Smokefree 2025 goal; advertising bans to control health

messaging around VLNC cigarettes; and the support of tobacco control advocates, smoker and non-smokers, including priority population groups such as Māori and Pacific Island peoples. Furthermore, proposals to legalise the sale and supply of nicotine-containing e-cigarettes and e-liquid as consumer products (Ministry of Health, 2017) may provide a novel opportunity for the development of a more comprehensive and integrated nicotine policy (Donny et al., 2016).

**2.3.3.2. *Electronic cigarettes.*** E-cigarettes may have a role in tobacco control by providing an alternative, safer source of nicotine instead of regular cigarettes. Existing NRT such as gum, patches, lozenges and inhalers are the most widely used smoking cessation aids (Ministry of Health, 2014d; West & Brown, 2012) and are recognised as a frontline treatment for smoking cessation (Batra, 2011; Fiore et al., 2008; National Institute for Health and Clinical Excellence, 2006; Zwar et al., 2011). However, efficacy and uptake are disappointingly low (Etter & Stapleton, 2006; Mills et al., 2012; Walsh, 2008), especially for women (Cepeda-Benito, Reynoso, & Erath, 2004). Poor pharmacokinetic profiles and insufficient dosages reduce the behaviourally reinforcing effects of nicotine such as alertness, stress reduction and social opportunities. As such, these products fail to address the wealth of behavioural and social habit-forming properties of smoking that are associated with the effects of nicotine via classical conditioning (Franck, Fillion, Kimmelman, Grad, & Eisenberg, 2016; Jarvis, 2004; Le Houezec, 2003). A device that retains the associated behavioural and sensory functions of cigarettes, such as e-cigarettes, could increase the likelihood of successful cessation and reduce tobacco-related harm.

E-cigarettes are handheld, battery-operated products that deliver an aerosol ‘vapour’, with or without nicotine, for inhalation. The vapour is generated by heating a solution typically made up of propylene, glycol or glycerol and flavouring agents rather than combustion of tobacco leaves. Since their introduction to the Chinese market in 2004, e-

cigarettes have gained popularity worldwide and reported use has increased every year (Breland et al., 2016; King, Patel, Nguyen, & Dube, 2015; McMillen, Gottlieb, Whitmore Schaefer, Winickoff, & Klein, 2014). Their unique combination of properties could have the potential to make them an effective tobacco harm reduction product (Farsalinos & Le Houezec, 2015). The comparable hand-mouth actions to smoking regular cigarettes and the resemblance of the exhaled vapour to cigarette smoke could effectively address the behavioural aspect of nicotine dependence while the delivery of nicotine could simultaneously address the physiological aspect (Buchhalter, Acosta, Evans, Breland, & Eissenberg, 2005). It has been argued that e-cigarettes have the potential to displace combustible cigarette smoking, functioning as the first truly ‘disruptive technology’ for the tobacco industry (Farsalinos & Le Houezec, 2015; Glynn, 2014; Hajek, 2014). However, it is important to note that the opinions of the public health community are divided.

Proponents of e-cigarettes support a tobacco harm reduction stance in which the substitution of low-risk nicotine products, such as e-cigarettes, for cigarette smoking is recognised as offering major public health benefits (Etter, 2013; Farsalinos & Le Houezec, 2015; Franck et al., 2016; Glynn, 2014; Hajek, 2014; Phillips, 2009). Advocates for this approach refer to a growing body of research supporting the argument that e-cigarettes can facilitate smoking cessation and reduction, are safer than tobacco, and are more well-liked and acceptable to smokers than other NRT products (Etter, 2013; Franck et al., 2016; Glynn, 2014). On the other hand, e-cigarette opponents do not support their use as a tobacco harm reduction product, instead advocating abstinence (Abrams, 2014). They focus on the incomplete evidence regarding their safety and cessation benefit, and express concerns that their availability will sustain nicotine addiction and subsequent harm by encouraging dual use, renormalizing smoking and acting as a gateway to tobacco smoking (Chapman, 2013; Grana, Benowitz, & Glantz, 2014; Hall, Gartner, & Forlini, 2015; Pisinger & Dossing, 2014).

The multitudes of problems with the evidence used to support these arguments have been highlighted elsewhere in a number of reviews (Farsalinos & Le Houezec, 2015; Franck et al., 2016). Overall, concerns about e-cigarettes appear to be based on hypothetical outcomes, with the majority of the supporting evidence based on misinterpretation and misapplication of cross-sectional evidence with methodological limitations. These limitations include toxicological studies testing e-liquid in liquid rather than vapour form or under unrealistic conditions, and cross-sectional research classifying e-cigarette use broadly (e.g.  $\geq 1$  day out of the past 30 days) and not controlling for population characteristics (Farsalinos & Le Houezec, 2015; Farsalinos & Polosa, 2014; Hajek, 2014). It is suggested that the data has often been misrepresented in the media and by authorities and regulators, and that the potential for harmful consequences of electronic cigarette use has been largely exaggerated (Polosa & Caponnetto, 2013). The current evidence supports the idea that e-cigarettes may be used as an effective tobacco harm reduction product and that the concerns of e-cigarette opponents are unlikely to play out.

Nonetheless, e-cigarettes are frequently presented to policymakers and consumers as a potentially less safe competitor to smoking cessation medications (including supported NRT products), rather than a consumer product that could compete with and potentially eliminate conventional cigarette smoking. For example, the World Health Organisation (WHO) take a position that discourages e-cigarette use and encourages strict regulation (World Health Organization, 2014). This is based on the evidence reviewed in a WHO-commissioned report (Grana, Benowitz, et al., 2014) which has been heavily criticised for overstating the risks by misinterpreting the evidence, and ignoring some of the most relevant, authoritative empirical studies and reviews (Bates, 2014; Hajek, 2014; Hajek et al., 2014). Such strict regulations have been implemented in many countries, though the level and restrictiveness varies. Although in some countries e-cigarettes are available as a consumer product, in others they

are regulated as a medicine or tobacco product, and in others there are bans on nicotine-containing e-liquid and even complete bans. Regulatory approaches that restrict the availability and accessibility of e-cigarettes more than tobacco, are paradoxical in that they pose as a barrier to a safer form of nicotine while allowing access to the more lethal form of nicotine delivery (Farsalinos & Le Houezec, 2015). Although some caution is necessary given the rapid evolution of e-cigarettes and their incomplete long-term risk profile, this alone should not act as a barrier to exploring the potential of e-cigarettes to act as a substitute for conventional cigarettes (Franck et al., 2016; Hajek et al., 2014). In particular, regulation surrounding safety and quality should be balanced with the need for acceptability and appeal to smokers to maximise the public health impact (Farsalinos & Le Houezec, 2015). Many advocates believe it is in public health interest to allow e-cigarettes to compete with conventional cigarettes but to achieve this they should not be regulated more restrictively than tobacco (Bates, 2014; Farsalinos & Le Houezec, 2015; Franck et al., 2016; Glynn, 2014; Hajek, 2014; Hajek et al., 2014; Hall et al., 2015). It is therefore important to consider to what extent e-cigarettes can function as a substitute for conventional cigarettes and thus compete with them in the market, which could theoretically lead to a greater reduction of harm and greater behavioural change.

Many properties of e-cigarettes may underlie their ability to function as substitutes for, and thus competitors to, conventional cigarettes. They are the only single product to simultaneously address nicotine withdrawal, psychological factors (withdrawal symptom alleviation) and behavioural cues that act as barriers to smoking abstinence. The subjective positive and negative reinforcing effects that may contribute to their ability to act as a substitute for conventional cigarettes may encourage smokers to substitute e-cigarettes for regular cigarettes. However, given the range of ways in which the subjective effects compare to those of regular cigarettes, the abuse liability of e-cigarettes may be relatively high, which

may perpetuate nicotine addiction and promote long-term uptake of a product with an unknown long-term risk profile.

*2.3.3.2.1. Subjective effects.* Many survey and experimental studies demonstrate that e-cigarettes can alleviate withdrawal symptoms. Early experimental studies using first-generation e-cigarettes found that e-cigarettes reduce withdrawal symptoms at a significantly lower rate than own brand conventional cigarettes (Bullen et al., 2010; Eissenberg, 2010). However, more recent studies using second- and third-generation e-cigarettes found no significant differences in desire to smoke between 16-24mg nicotine e-cigarettes and regular cigarettes, suggesting that e-cigarettes can reduce withdrawal symptoms and craving at a similar level to tobacco cigarettes (D'Ruiz, Graff, & Yan, 2015; McPherson et al., 2016; Wagener et al., 2014) and other NRT products such as nicotine inhalers (Bullen et al., 2010; Walele, Sharma, Savioz, Martin, & Williams, 2016b). Given the rapid evolution of e-cigarettes and the improvements in nicotine delivery (Farsalinos, Spyrou, et al., 2014), it is important to note that older studies using early models may not be relevant for the assessment, and regulation, of newer, higher quality devices.

Given the range of nicotine concentrations available for e-cigarettes, it is important to consider the effects of nicotine on alleviating withdrawal symptoms. Significantly greater reductions in desire to smoke and withdrawal symptoms were reported after using 16-18mg nicotine e-cigarettes than after using 0mg e-cigarettes (Bullen et al., 2010; Dawkins, Turner, & Crowe, 2013; Dawkins, Turner, Hasna, & Soar, 2012). Przulj, McRobbie, and Hajek (2016) compared a 0mg e-cigarette with a distraction tool (stress ball) to test whether the reductions in withdrawal symptoms seen in previous studies were due to shared sensory and behavioural components with cigarette smoking or a distraction effect. They found significantly greater reductions in urge to smoke and withdrawal symptoms after using the 0mg e-cigarette compared to the distraction tool, which suggests that the sensory and

behavioural functions alleviate withdrawal symptoms even when using a 0mg e-cigarette. To date only one study has compared multiple nicotine levels. (Walele et al., 2016b) compared responses to four different nicotine levels (0mg, 4mg, 9mg and 20mg) after four controlled hourly self-administration of 10 inhalations of each cartridge on consecutive days. They found that the level of nicotine had no effect on withdrawal symptoms or craving. However all four cartridges failed to reach high levels in the blood, and as such poor nicotine delivery may explain these results (Walele, Sharma, Savioz, Martin, & Williams, 2016a).

A range of measures of appeal, enjoyment and satisfaction have been used in experimental and survey studies including single-item ‘satisfaction’ or ‘pleasantness to use’ on a visual analogue scale (VAS) (Bullen et al., 2010; Dawkins & Corcoran, 2014; Grace, Kivell, & Laugesen, 2015b; Vansickel, Cobb, Weaver, & Eissenberg, 2010; Vansickel, Weaver, & Eissenberg, 2012) and multiple item measures such as the Modified Cigarette Evaluation Questionnaire (mCEQ) (Cappelleri et al., 2007; Rose et al., 2000) and the Direct Effects of Smoking Scale (Kleykamp, Jennings, Sams, Weaver, & Eissenberg, 2008). E-cigarettes are typically rated as satisfying and pleasant to use in experimental (Bullen et al., 2010; Dawkins & Corcoran, 2014; Grace et al., 2015b; Steinberg et al., 2014; Vansickel et al., 2010; Vansickel et al., 2012) and survey studies (Dawkins, Turner, Roberts, & Soar, 2013). They are often rated significantly lower than regular cigarettes for positive effects (such as satisfaction, taste and pleasantness) but similar for negative or adverse effects (such as dizziness, sickness and harshness) by smokers with no prior e-cigarette experience (Grace et al., 2015b; McPherson et al., 2016; Vansickel et al., 2010; Wagener et al., 2014; Walele et al., 2016b). E-cigarettes have also been compared to other NRT products such as nicotine inhalers, wherein studies have found that nicotine-containing e-cigarettes are rated as least as satisfying as nicotine inhalers (Bullen et al., 2010; Steinberg et al., 2014) and more pleasant to use, rewarding, acceptable and likely to be used or recommended as a cessation tool

(Bullen et al., 2010; Steinberg et al., 2014). These studies suggest that e-cigarettes may be more appealing to smokers than other NRT products and they may be more likely to recommend and use e-cigarettes to quit smoking, which suggests that the availability of e-cigarettes may encourage smokers to make attempts to quit.

The subjective effects of e-cigarette use may vary by gender. Dawkins et al. (2012) found that males showed significantly greater overall reductions in anxiety, irritability and restlessness using an 18mg e-cigarettes compared to a 0mg or 'just hold' condition (holding but not using the e-cigarette). In contrast, females showed significantly greater reductions in depression using the 18mg and 0mg e-cigarettes compared to the 'just hold' condition. These results suggest that the delivery of nicotine could be more important for males, whilst the sensory and behavioural properties may be more important for females. This is consistent with the idea that nicotine is more reinforcing for males (Perkins, Donny, & Caggiula, 1999; Perkins et al., 2002; Perkins & Karelitz, 2015) and females are more susceptible to social and behavioural smoking cues (Doran, 2014; Perkins et al., 2001). Another study found that females rated nicotine-containing e-cigarettes significantly more satisfying than males on a single-item measure (Grace, Kivell, & Laugesen, 2015c). This is important because other NRT products (nicotine gum) have been found to be less effective long-term for women than men (Cepeda-Benito et al., 2004). In contrast, e-cigarettes may be a particularly effective NRT product for women by mimicking the social and behavioural cues associated with smoking.

Overall the evidence suggests that second- and third-generation e-cigarettes can alleviate withdrawal symptoms and craving to a similar degree to regular cigarettes. Although they are rated as less enjoyable and satisfying than regular cigarettes, they seem to be more appealing to smokers than other nicotine delivery devices. The finding that nicotine-containing e-cigarettes reduce withdrawal and craving more than placebo e-cigarettes



suggests that placebo devices can replicate some of the behavioural aspects that may have become conditioned reinforcers, but that the direct effects of nicotine produce greater effects. To date the characteristics of the relationship between nicotine content and the subjective effects of e-cigarettes is unclear. Given the range of nicotine concentrations available on the e-cigarette market and the potential for the perpetuation of addiction and abuse liability, it may be important to evaluate what levels of nicotine would be optimal for encouraging uptake but minimising abuse liability.

2.3.3.2.2. *Demand.* There are relatively few studies that examine demand for e-cigarettes, though a range of methodologies have been used. One way is to use discrete choice procedures. One such procedure, the multiple choice procedure (MCP), requires participants to make discrete choices between novel or habitually used drugs or increasing monetary values (Griffiths, Rush, & Puhala, 1996; Griffiths, Troisi, Silverman, & Mumford, 1993). The primary outcomes measures are the crossover value (the monetary value at which participants chose to receive money over the drug) and the percentage of participants choosing to use a novel drug over a habitually used drug when given a discrete choice (McPherson et al., 2016). Studies using the MCP found a significantly lower crossover value for e-cigarettes than regular cigarettes, suggesting that regular cigarettes have a higher comparative value than e-cigarettes for smokers (McPherson et al., 2016; Vansickel et al., 2012). When required to choose between a conventional cigarette and an e-cigarette, studies have found that smokers chose the conventional cigarette more often than e-cigarettes often (Marti, Buckell, Maclean, & Sindelar, 2016; McPherson et al., 2016). Marti et al. (2016) conducted an online discrete choice task which required smokers to make repeated choices between regular cigarettes and e-cigarettes as specific attributes (price, health impact, potential to help quit smoking and bans in public places) were varied. When the sample were divided into smokers (seldom diverted from choosing conventional cigarettes), vapers

(seldom diverted from choosing e-cigarettes) and dual users (choice varied depending on attribute scenarios), smokers were most price sensitive and placed little value on non-price attributes. Maintaining a price differential between conventional and e-cigarettes may be a useful way to encourage switching to e-cigarettes for individuals who would otherwise choose to continue smoking conventional cigarettes (Marti et al., 2016).

Another approach is to calculate the price elasticity of demand and CPE of e-cigarettes. An econometric study used quarterly e-cigarette price and sale data, and conventional cigarette price data in the US from 2009-12 to estimate price elasticity of demand (Huang et al., 2014). Price elasticity of demand for disposable and reusable e-cigarettes clustered around -1.2 and -1.9 respectively, indicating that if the price increased by 10%, consumption would decrease by 12 or 19% respectively. These elasticity estimates are higher than estimates for tobacco cigarettes which cluster around -0.4 (Gallet & List, 2003; IARC Working Group, 2011). The authors suggest that this may be due to experimental use of novel products being more sensitive to price and the limited sources of data (collected only from participating in-store retailers). They proposed that the price elasticity of demand for the overall e-cigarette market would be more inelastic (Huang et al., 2014). Cigarette prices were positively associated with sales of e-cigarettes, however this relationship was not statistically significant and CPE was not reported. Another econometric study used pooled time-series data on regular and e-cigarette sales and prices in six EU markets from 2011-14 (Stoklosa, Drope, & Chaloupka, 2016). Price elasticity of demand for e-cigarettes varied from -0.79 to -0.84. There was also some evidence that e-cigarettes may function as a substitute for conventional cigarettes, which included that higher cigarette prices were associated with increased e-cigarette sales, with CPE estimates of 4.55 (using a static model) and 3.6 (using a dynamic model controlling for addiction). This indicates that a 10% increase in the price of conventional cigarettes was associated with a 40% increase in e-cigarette sales. The high CPE

estimate was hypothesised to reflect the relatively small size of the e-cigarette market compared to the conventional cigarette market.

Although the CPT has not been used to generate demand data for e-cigarettes to date, it may be applicable due to the similar intended use and function to cigarettes. However other simulated demand tasks have been used. Grace et al. (2015b) used a cross-price task to calculate the CPE of e-cigarettes in a sample of New Zealand smokers who had sampled an e-cigarette. Smokers were asked how many conventional cigarettes and e-cigarettes they would consume per day at three increasing prices of conventional cigarettes (0.5x, 1x and 2x current market price) with e-cigarettes available at a constant, reduced price. CPE was estimated as 0.16, which was significantly positive and indicated that if the price of tobacco cigarettes were to increase by 10%, consumption of e-cigarettes would increase by 1.6%. They also compared demand for tobacco cigarettes at the same three prices on the CPT (assuming only conventional cigarettes are available) and on the cross-price task (assuming e-cigarettes are available at a constant, reduced price). On average, simulated demand for conventional cigarettes decreased by 35.8% when e-cigarettes were available. Together, these results suggest that e-cigarettes are partially substitutable for conventional cigarettes and their availability would reduce tobacco consumption. However, at the highest price on the cross-price task (2x current market price) e-cigarette availability did not significantly reduce demand for conventional cigarettes and a significantly lower proportion of participants said they would quit smoking at this price on the cross-price task compared to the same prices on the CPT. Grace et al. (2015b) hypothesised that at high prices, smokers may find it easier to maintain smoking occasional conventional cigarettes supplemented by less-expensive e-cigarettes than if they were solely limited to smoking the expensive cigarettes. This suggests that if cigarette prices are high, the availability of e-cigarettes as a much less expensive option may have the unintended consequence of maintaining conventional cigarette smoking

for some smokers who otherwise may have quit. The authors proposed that it would be important to coordinate a tax strategy in which both e-cigarettes and conventional cigarettes increase in price while maintaining a price differential in favour of e-cigarettes to encourage use of the less harmful product.

Quisenberry, Koffarnus, Hatz, Epstein, and Bickel (2016) simulated a virtual experimental tobacco marketplace (ETM) where regular cigarettes, e-cigarettes, snus, nicotine gum, nicotine lozenges and cigarillos were available in a virtual online store at manipulated prices. Using an allocated account balance, participants were instructed to make one week's worth of purchases under four randomly ordered prices of usual brand cigarettes while the other products remained constant. The data did not fit the exponential model and so a linear regression was performed to determine cross-price elasticity based on the slopes. As price increased the greatest demand was observed for cigarillos and e-cigarettes. Cigarillos had the greatest slope but variability in the slope meant it was not significantly different from zero, while e-cigarettes had a lower slope but it was significantly different from zero. When cigarillos were removed, consumption of e-cigarettes and snus were the greatest, both with slopes significantly different from zero. This indicates that the presence or absence of a particular product may influence the substitutability of others. Nonetheless, e-cigarettes were the only harm reduction product to consistently function as a substitute for conventional cigarettes regardless of the other products available.

Although there is limited research on demand and cross-price elasticity of e-cigarettes, the available research suggests that e-cigarettes are at least partially substitutable for conventional cigarettes. If they were available at a lower price than conventional cigarettes their availability would be likely to reduce cigarette consumption, though specific price differentials should be maintained and closely monitored to ensure that e-cigarettes do

not become disproportionately more affordable than regular cigarettes due to the risk that they may prevent absolute smoking cessation.

2.3.3.2.3. *Patterns of behaviour.* If e-cigarettes function as substitutes for conventional cigarettes and alleviate withdrawal symptoms, it would be expected that they would modify smoking patterns either by reducing smoking or encouraging cessation. Whereas absolute cessation offers the greatest public health benefits, a large proportion of smokers are either unwilling or unable to quit and there is a growing interest in the potential for reducing harm by encouraging smokers to reduce the number of cigarettes they smoke and thus their exposure to tobacco toxins (Shiffman et al., 2002; Stratton, Shetty, Wallace, & Bondurant, 2001). Reducing daily cigarette consumption has been shown to significantly improve biomarkers of cardiovascular diseases but produces only modest reductions in risk of disease (Pisinger & Godtfredsen, 2007). This has been hypothesised to be due to similar toxicant exposure due to compensatory smoking of fewer cigarettes more intensively, the length of time reductions need to persist before health benefits occur, and a potentially steep dose-response curve requiring reductions to very low levels before health benefits are observed (Hughes & Carpenter, 2006). The literature is limited by the small number of studies, small sample sizes, inconsistent definitions of successful reduction and variance in baseline smoking rates; as such conclusions cannot be drawn, though the benefits are likely to be small. There are concerns that encouraging smoking reduction undermines motivation to quit (Stratton et al., 2001), however reviews of controlled, cohort, case-control and experimental studies have shown that smokers who reduce their daily cigarette consumption are more likely to quit smoking in the future (Begh et al., 2015; Hughes & Carpenter, 2006; Hyland et al., 2005; Klemperer & Hughes, 2016) which would lead to significant public health gains. Therefore, rather than reduction itself leading to positive health outcomes, it is likely that reduced smoking may constitute a first step to attempt and subsequently achieve

abstinence for some smokers (Hughes & Carpenter, 2006). Thus, changes to patterns of smoking behaviour as a result of e-cigarette use are an important outcome measure.

There is some controversy over the role of e-cigarettes in smoking cessation and reduction due to methodological problems, relatively few and often small studies, inconsistencies and contradictions in results, and a lack of long term follow-up (Pisinger, 2014). Survey studies typically recruit large numbers of e-cigarette users in a time- and cost-efficient manner. However they rely on retrospective self-report data, often from experienced e-cigarette users from online vaping communities or vape stores who may have a vested interest in portraying e-cigarettes in a positive light. As such, the results of these studies must be interpreted with caution. Prospective cohort studies describe changes in smoking behaviour in smokers provided with e-cigarettes to reduce or stop smoking for follow-up for periods of 6-24 months. However, these studies lack experimental controls therefore causal associations cannot be made and they cannot be compared to other products. Randomised controlled trials (RCTs) are more rigorously controlled through participant randomisation, double blinding and the inclusion of control or comparison groups. While they have strong internal validity, there are some arguments that RCTs do not reflect real-world effectiveness, especially for NRT products (Hughes, Peters, & Naud, 2011; Kotz, Brown, & West, 2014; West & Zhou, 2007). They are also more costly and time-consuming and as such there are a limited number of RCTs to draw on regarding the efficacy of e-cigarettes for smoking cessation and reduction. Though the evidence must be interpreted with the specific limitations of these studies in mind, there is some support for the role of e-cigarettes in aiding smoking cessation and reduction.

Many survey studies have found a significant relationship between e-cigarette use and increased incidence of smoking cessation (Biener & Hargraves, 2015; Brown, Beard, Kotz, Michie, & West, 2014; Dawkins, Turner, Roberts, et al., 2013; Etter & Bullen, 2014;

Farsalinos, Romagna, Tsiapras, Kyrzopoulos, & Voudris, 2013b, 2014; Hitchman, Brose, Brown, Robson, & McNeill, 2015; Polosa, Caponnetto, Cibella, & Le-Houezec, 2015; Polosa, Caponnetto, Maglia, Morjaria, & Russo, 2014; Tackett et al., 2015) and an increased intention to quit smoking or to use e-cigarettes to quit smoking (Kalkhoran, Grana, Neilands, & Ling, 2015; Popova & Ling, 2013; Pulvers et al., 2015; Rutten et al., 2015). However others reported an increased likelihood of cessation attempts but this was not linked to the likelihood of long term abstinence (Brose, Hitchman, Brown, West, & McNeill, 2015; Pearson et al., 2015). Furthermore, two prospective survey studies reported that smokers who had ever used e-cigarettes were significantly less likely to quit than those who had never used e-cigarettes (Al-Delaimy, Myers, Leas, Strong, & Hofstetter, 2015; Vickerman, Carpenter, Altman, Nash, & Zbikowski, 2013). However these studies have been criticised for failing to take into account intended use of e-cigarettes (e.g. experimental, recreational, dual use or smoking cessation) and were not intended to assess the effectiveness of e-cigarettes as a mechanism to quit (Farsalinos & Le Houezec, 2015). Many survey studies also report reductions in the number of cigarettes smoked per day (Berg, Barr, Stratton, Escoffery, & Kegler, 2014; Etter & Bullen, 2014; Farsalinos, Romagna, et al., 2014; Polosa et al., 2015; Polosa, Morjaria, Caponnetto, Campagna, et al., 2014; Polosa, Morjaria, Caponnetto, Caruso, et al., 2014; Tackett et al., 2015). However one study reported no significant changes in cigarettes smoked per day (Grana, Popova, & Ling, 2014) and another reported that smokers who used e-cigarettes were significantly less likely to decrease cigarette consumption (Al-Delaimy et al., 2015). Among cohort studies, abstinence rates ranged from 10-50% (Caponnetto, Auditore, Russo, Cappello, & Polosa, 2013; Choi & Forster, 2014; Ely, 2013; Manzoli et al., 2015; McRobbie et al., 2015; Polosa et al., 2015; Polosa et al., 2011) which are higher than estimates of unassisted cessation rates in a meta-analysis (7.33%) (Baillie, Mattick, & Hall, 1995). However as these studies did not include comparison groups it

cannot be determined whether these results are due to the e-cigarettes themselves or participant characteristics. Thus the majority of the evidence from survey and cohort studies supports that e-cigarette use may lead to increased likelihood of cessation and reductions in cigarettes smoked per day; though there are some discrepancies which may be related to methodological limitations, as described above.

Three randomised controlled trials have been conducted to compare the efficacy of e-cigarettes with various comparison groups. Two large RCTs [ $N=657$  and  $300$  respectively] using first-generation e-cigarettes showed abstinence rates for nicotine-containing e-cigarettes (5.4, 7.2 and 16mg) than placebo e-cigarettes (0mg) (Bullen et al., 2013; Caponnetto, Campagna, et al., 2013), and similar abstinence rates to 21mg nicotine patches (Bullen et al., 2013). However effect sizes were relatively small which may be due to poor nicotine delivery and a lack of behavioural cessation support (McRobbie, Bullen, Hartmann-Boyce, & Hajek, 2014). These studies suggest that nicotine in e-cigarettes is important for smokers to abstain from smoking; however more research is needed to determine whether there is an optimal level of nicotine. In a much smaller RCT [ $N=48$ ], Adriaens, Van Gucht, Declerck, and Baeyens (2014) reported abstinence rates of 34% after 2 months of 16mg e-cigarette use, compared to 0% for a control group who did not receive e-cigarettes. This abstinence rate is markedly higher than those observed in the first two randomised controlled trials, and Adriaens et al. (2014) hypothesise that the use of newer, higher-quality devices in their study may have contributed to the higher quit rates relative to trials using now-obsolete first-generation devices. These limitations may reflect the rapidly evolving e-cigarette market and highlight the need for ongoing research to provide up-to-date evidence for the efficacy of the most relevant e-cigarette models.

The results of cross-sectional studies, prospective cohort studies and RCTs also show substantial rates of smoking reduction among e-cigarette users (Brown et al., 2014; Bullen et



al., 2013; Caponnetto, Auditore, et al., 2013; Caponnetto, Campagna, et al., 2013; Etter & Bullen, 2014; Manzoli et al., 2015; Polosa et al., 2011; Polosa, Morjaria, Caponnetto, Campagna, et al., 2014; Rahman, Hann, Wilson, Mnatzaganian, & Worrall-Carter, 2015; Siegel, Tanwar, & Wood, 2011), with at least 50% reduction in daily cigarette consumption in 50-57% of participants (Bullen et al., 2013; Caponnetto, Auditore, et al., 2013; Caponnetto, Campagna, et al., 2013; Polosa et al., 2011; Polosa, Morjaria, Caponnetto, Campagna, et al., 2014). Only two studies, both RCTs, compared different nicotine strengths, and again there were mixed findings regarding the role of nicotine. Caponnetto, Campagna, et al. (2013) found that nicotine-containing e-cigarettes showed significantly greater reductions than non-nicotine e-cigarettes while Bullen et al. (2013) found no significant differences. Again, the role of nicotine is unclear and additional research is required to determine which levels of nicotine would lead to optimal behavioural change for smokers.

Though methodological limitations must be considered, a wealth of research suggests that the use of e-cigarettes leads to modifications of cigarette smoking behaviour including cessation and reductions in some smokers motivated or unmotivated to quit. This supports the idea that e-cigarettes may function as a substitute for at least some components of a conventional cigarette smoking habit and that their availability may help smokers choose to make changes to their smoking behaviour. The results of some RCTs suggest that the presence of nicotine is an important factor in determining changes in smoking behaviour, though the effects are modest and nature of this relationship is unclear.

*2.3.3.2.4. Summary and application to New Zealand.* E-cigarettes may play a role in tobacco control policy by providing a more acceptable and attractive alternative source of nicotine than existing NRT. By delivering nicotine and mimicking the sensory and behavioural aspects associated with smoking, e-cigarettes have the potential to replace both the primary reinforcing effects of nicotine and the conditioned sensory reinforcing effects.

The research to date suggests that the presence of nicotine is likely an important factor in alleviating withdrawal symptoms, particularly for males, however there is a lack of research comparing the range of nicotine levels available on the market. Given the addictive nature of nicotine and the range of strengths of nicotine e-liquids and cartridges available, it is important to understand the relationship between nicotine levels and the subjective effects of, demand for and patterns of use of e-cigarettes. This will help determine optimal nicotine levels for effective behaviour change whilst minimising abuse liability.

These research questions are relevant for New Zealand where the Government has supported an aspirational Smokefree 2025 goal but e-cigarettes have a complex regulatory status. Up until 2017, e-cigarettes and e-liquids containing nicotine were not permitted for sale in New Zealand, while non-nicotine e-cigarettes and e-liquid could be legally sold. These restrictions were a result of the classification of nicotine in e-cigarettes or e-liquid as an ‘oral tobacco product’ or a medicine as specified by the Smokefree Environments Act 1990 and the Medicines Act 1981, which were developed before the emergence of these products. However the Ministry of Health acknowledged the paradoxical status of e-cigarette regulation in a consultation document in 2016, and proposed to make legislative changes to maximise the potential benefits of e-cigarettes and minimise the potential risks to smokers and the wider population (Ministry of Health, 2016). Based on a review of the evidence on the risks and benefits of e-cigarettes, a review of international regulatory approaches, and public consultation, the Ministry of Health made recommendations to the Government to amend the Smoke-free Environments Act 1990 to legalise the sale and supply of nicotine e-cigarettes and e-liquid as consumer products, but with restrictions (Ministry of Health, 2017). These restrictions included prohibiting the sale and supply of nicotine and non-nicotine e-cigarettes and e-liquids to people under the age of 18 years, regulating promotion and advertising in line with tobacco restrictions, and enabling the regulation of product safety

requirements. These legislative changes are unlikely to be implemented until at least mid-2018 and will be reviewed within five years of commencement due to the developing nature of the e-cigarette evidence base, highlighting the importance of ongoing monitoring.

One of the issues highlighted by the Ministry of Health is whether excise taxes should be applied to nicotine e-liquid (Ministry of Health, 2017). There is limited evidence from which to base estimates of the impact of excise taxes on e-cigarette use. Studies suggest that e-cigarettes are partially substitutable for regular cigarettes and their availability could reduce demand for regular cigarettes (Grace et al., 2015b; Quisenberry et al., 2016; Stoklosa et al., 2016). However, e-cigarette sales have also been shown to be very responsive to their own price changes, suggesting that imposing excise taxes on e-cigarettes could potentially lead to significant reductions in e-cigarette use (Amato & Boyle, 2016; Huang et al., 2014). Chaloupka, Sweanor, and Warner (2015) propose an approach that differentially taxes nicotine products based on risk to maximise incentive to switch from the most harmful products to the least harmful. Whereas taxes on e-cigarettes should be high enough to discourage initiation, prices should remain lower enough to maximise the likelihood of current smokers switching to e-cigarettes and deter e-cigarette users from switching to cigarettes. More research is needed to evaluate how demand for e-cigarettes is impacted by their own price and the price of cigarettes, and which combinations of price would be of most public health benefit in New Zealand, particularly within the context of changes in policy, smoking-related health inequalities between ethnic groups and the smokefree 2025 goal.

## **2.4. Summary and Outline of Studies**

The overall goal of this thesis is to examine price policy and the utility of alternative products in New Zealand at a time when the Government is aiming for a smokefree goal. The psychological research described in this thesis uses behavioural economic methods to understand how these policies affect demand, subjective effects and patterns of use of

cigarettes and alternative products. The literature review has described the application of behavioural economic concepts and methodologies to tobacco prices and the availability of alternative products. The following five chapters describe five empirical studies of tobacco control related to price policy, alternative products and the application of these concepts to the tobacco control context in New Zealand.

The first two studies use data from the Cost of Smoking Study (Grace et al., 2014, 2015a, 2015b, 2015c) to compare smoking behaviour, demand, subjective effects, and cross-price elasticity for e-cigarettes for New Zealand European and Māori and Pacific Island smokers (Tucker et al., 2017; Tucker, Bullen, et al., 2017a; Tucker, Kivell, et al., 2017). The following chapters report behavioural economic and psychological data from two original laboratory studies and one field study. The first laboratory study examined subjective effects and demand for VLNC cigarettes and regular cigarettes (Tucker et al., 2017), and the second laboratory study examined subjective effects and demand for e-cigarettes with cartridges of varying nicotine content for first-time users, including predicting simulated demand based on subjective effects ratings (Tucker et al., 2017a). Finally, the field study examined subjective effects, e-cigarette use behaviour and smoking behaviour over a two week period when e-cigarettes of varying nicotine contents were available (Tucker et al., 2017b). This study also tested whether the same subjective effects identified as predictive of hypothetical demand can be used to predict actual e-cigarette use.

All of the studies in the following chapters have been prepared as individual manuscripts for publication and as such there is some repetition in the introduction and method sections of each chapter. It is hoped that these studies will highlight the utility of behavioural economic methods for the study of tobacco control, and contribute to the knowledge base informing tobacco control policy with particular relevance to the current context in New Zealand.

## CHAPTER 3

### Changes to Smoking Habits and Addiction Following Tobacco Excise Tax Increases: A Comparison of Māori, Pacific and New Zealand European Smokers

#### 3.1. Preface

Tobacco excise tax is a fundamental part of New Zealand's comprehensive tobacco control programme, with annual 10% tobacco excise tax increases implemented since 2010 and planned until 2020. These policies are operating within a complex social context including a national goal to be smokefree (<5% prevalence) by 2025, and significant inequalities in smoking prevalence between Māori and Pacific Island New Zealanders and those of European descent. Thus it is important to monitor the overall effectiveness of these strategies and the comparative effectiveness for different ethnic groups in achieving the Smokefree 2025 goal. This chapter aims to evaluate whether tobacco excise taxes are likely to contribute towards reducing inequalities in smoking and smoking-related health outcomes for Māori and Pacific Island people in New Zealand by comparing changes in smoking behaviour in response to two annual 10% tobacco excise tax increases from 2012 to 2014. Existing evidence is mixed, and has only evaluated changes after one tax increase. To our knowledge, this is the first study to examine behaviour trends over more than one tax increase.

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Tucker, M. R., Kivell, B. M., Laugesen, M. & Grace, R. C. (2016) Changes to smoking habits and addiction following tobacco excise tax increases: a comparison of Maori, Pacific and New Zealand European smokers. *Australian and New Zealand Journal of Public Health*, 41 (1), 92-98. doi: 10.1111/1753-6405.12603.

### 3.2 Abstract

This study compares changes in smoking habit and psychological addiction in Māori/Pacific and NZ European smokers in response to two annual excise tax increases from 2012-2014. Smokers from New Zealand cities completed questionnaires at three time points before and after two excise tax increases. There were no significant differences in cigarettes per day or psychological addiction at baseline, but a linear decline in both measures was observed in Māori/Pacific and NZ European smokers. Cigarettes per day reduced at a greater rate for Māori/Pacific than NZ European smokers but dependence did not. Results indicated that Māori/Pacific smokers' demand for cigarettes may be more price sensitive than NZ European smokers. Tobacco excise tax may be particularly effective for Māori/Pacific smokers and may contribute to reductions in smoking-related health inequalities in New Zealand.

### 3.3. Introduction

New Zealand has had a progressive tobacco control programme since 1985 with the ultimate goal of achieving a smokefree population (<5% prevalence) by 2025. This reflects growing interest in an ‘endgame’ scenario with strategies targeted towards achieving near-zero smoking prevalence (Edwards, Russell, Thomson, Wilson, & Gifford, 2011). In addition to achieving a smokefree population, in recent years there has been increasing emphasis on reducing inequalities in smoking-related health outcomes. Smoking is a major contributor to inequalities in health outcomes observed between ethnic groups in New Zealand, notably the consistently poor outcomes for Māori and Pacific Island people (Blakely et al., 2004; Howden-Chapman & Tobias, 2000; Wamala et al., 2006). Smoking prevalence among Māori (35.5%) and Pacific Island groups (22.8%) is elevated compared to New Zealanders of European descent (NZ European) (12.5%) (Ministry of Health, 2016).

A range of strategies have been employed in New Zealand in attempt to achieve the dual health goals of reducing smoking prevalence and inequalities in smoking and smoking-related outcomes. These include smokefree environments, public health programmes and an increasing range of cessation support (Glover et al., 2013). One strategy has been to increase the price of tobacco by raising the excise tax on tobacco products. International evidence suggests that excise tax is one of the most effective single tobacco control measures and has considerable support from cross-sectional population surveys and macroeconomic studies (Chaloupka et al., 2011; Chaloupka et al., 2012; Dunlop et al., 2011; Gallet & List, 2003; Gallus et al., 2006; Hanewinkel & Insensee, 2006). Increasing tobacco excise tax is also seen as one way to target lower socioeconomic groups, who have been shown to be more price sensitive (Wilson, 2007; Wilson & Thomson, 2005; Wilson et al., 2010). Because Māori and Pacific Island people are economically disadvantaged (Salmond et al., 2012), excise taxes may be particularly effective at achieving reductions in smoking for these groups. Achieving

reductions in smoking prevalence is particularly important among Māori and Pacific Island smokers in order to reduce health inequalities and achieve the Smokefree 2025 goal.

There were substantial increases in tobacco excise taxes in New Zealand in the 1980s, in 1991, 1998 and 2000; however there were no increases (in real terms) between 2000 and 2009. In April 2010, the New Zealand Government raised tobacco excise by 10 % on factory made (FM) cigarettes and by 24% on ‘roll your own’ (RYO) tobacco, followed by two annual 10% increases in 2011 and 2012. In October 2012, the Customs and Excise (Tobacco Products – Budget Measures) Amendment Act 2012 legislated for a further four 10% tax increases to come into effect on 1 January each year from 2013-2016 (Li, Walton, & Newcombe, 2015). These efforts have provided opportunities to examine smoking-related responses to tax increases in terms of rates of quitting altogether, quit attempts and cutting down on smoking.

After two tax increases in 2010 and 2011, considerable cross-sectional evidence suggests that smokers experienced increased pressure to quit. The volume of Quitline calls in May 2010, following the first excise tax increase, exceeded those in May 2008 and 2009 (Salmon & Ball, 2010) and both telephone and face-to-face surveys suggest that there was a significant increase in the amount of smokers’ making quit attempts or smoking-related changes (Cowie et al., 2014; MacFarlane et al., 2011). Walton and colleagues (2013) surveyed New Zealand smokers three months before and after the 2012 tax increase and found an increase in smoking-related behavioural change including quitting altogether, quit attempts and cutting down on smoking, although non-Māori smokers were less likely to report a change in smoking behaviour. Grace, Kivell and Laugesen (2014) interviewed New Zealand smokers before and after the 2013 tax increase and found that participants reported a significant reduction in cigarettes per day and self-report measures of addiction.



The overall impact of New Zealand tax policy on tobacco reduction, amongst other measures, appears to be effective, and many advocate more tax increases to encourage quitting (Cowie et al., 2014). Although research on price sensitivity across ethnic groups is limited, some studies have been carried out in the US that examine racial and ethnic differences in tobacco price sensitivity focusing specifically on Hispanic and African Americans compared to White Americans. These studies support the idea that Hispanic and African American smokers are more responsive to tax and price than White Americans (Chaloupka & Pacula, 1999; Farrelly et al., 2001; Gruber & Zinman, 2001; Myers, Edland, Hofstetter, & Al-Delaimy, 2013; Tauras, 2007). However it is unclear whether these findings can be generalised to minority groups in New Zealand. Some authors argue that while mainstream public health programs have the potential to improve average health outcomes, they do so at the expense of increasing health inequalities (Hill et al., 2005).

There is concerning evidence that, smoking prevalence among Māori and Pacific Island groups remains high, despite intensive tobacco control strategies and a policy focus on reducing inequalities (Ministry of Health, 2014d; Salmond et al., 2012). Hill and colleagues (2005) examined reductions in smoking prevalence between 1981 and 1996 and found that these were primarily driven by a decrease in smoking among high socioeconomic groups and the non-Māori and non-Pacific Island population. Similarly, Salmond et al. (2012) studied reductions in smoking prevalence between 1996 and 2006 and concluded that Māori continue to have an “exceedingly high prevalence of smoking despite a policy focus on reducing disparities in smoking” (p.668) and stated concerns that smoking prevalence in Pacific Island populations may not yet have reached its peak based on modest increases over the decade.

These findings indicate that that current tobacco control policies, including excise tax increases, may not motivate cessation in Māori and Pacific Island groups. However, smoking prevalence does not tell the whole story. Alternative responses to excise increases may

include smoking fewer cigarettes per day, smoking closer to the filter, rolling thinner cigarettes (for those that use roll-your-own cigarettes), switching to cheaper brands or switching from roll-your-own to factory-made cigarettes (Cowie et al., 2014). Although these responses may not be associated with the same health benefits as absolute cessation, some evidence suggests that smoking reduction is associated with greater probability of future quitting (Hughes & Carpenter, 2006) and so these changes may still be considered favourable. Studies that compared these responses between different population groups reported mixed results. Some reported significantly greater reductions in cigarettes per day in Māori and Pacific Island groups following tax increases (Grace et al., 2014) while others reported greater reductions in NZ European groups (Walton et al., 2013). The latter pattern of results is especially concerning if, despite being a priority group for tobacco control, Māori are not benefited by excise tax increases.

However, it must be noted that the role of tobacco taxation on the above findings is unclear. Tax policy is generally seen as one of the more effective approaches for reducing tobacco consumption in lower socioeconomic groups; but other tobacco control measures are also being applied simultaneously and the effects of these measures may not have been considered. For example, some authors suggest that public health promotion messages have their greatest initial impact on higher socioeconomic groups with greater educational attainment and access to resources (Acheson, 1998), and thus Māori and Pacific Island people may have benefited less from such mainstream public health tobacco control interventions. This highlights the need to use targeted strategies for different population groups if New Zealand is to achieve the goal of Smokefree Aotearoa 2025 (Hill et al., 2005).

As far as we are aware there is no existing research that compares psychological measures of nicotine dependence and addiction in Māori/Pacific and NZ European smokers, or any research that has evaluate changes in psychological dependence and addiction following

excise tax increases. While there has been research investigating individual smokers' responses before and after a single tobacco excise increases in New Zealand (Cowie et al., 2014; Grace et al., 2014; MacFarlane et al., 2011; Salmon & Ball, 2010; Walton et al., 2013), and two previous studies that compare these responses by ethnicity (Grace et al., 2014; Walton et al., 2013), our study is the first to compare Māori/Pacific and NZ European smokers at three time points before and after two annual tobacco excise increases. The goal of the present study was to evaluate how these groups of smokers responded in terms of changes in smoking habit, to two successive 10% excise tax increases.

### **3.4. Method**

**3.4.1. Participants.** Adult smokers (N=357) were recruited by newspaper, community and internet advertising from four major New Zealand cities: Auckland (N=72), Wellington (N=151), Christchurch (N=71) and Dunedin (N=63). Participants were required to be adult daily smokers, over 18 years old, who purchased their own tobacco and had no intention to quit. Pregnant or breastfeeding women were excluded. 357 participants were included in the analysis with a mean age of 36.95 (SD = 13.39).

All aspects of the study were approved by the University of Canterbury Human Ethics Committee and participants provided written consent.

**3.4.2. Procedure.** 337 participants attended sessions at Wave 1 in November-December 2012 and 226 attended at Wave 2 in February-March 2013. 152 participants were contacted by telephone or email at Wave 3 in February-March 2014 and provided with a link to an online questionnaire. All participants received an NZ\$15 shopping mall vouchers and a chance to win a NZ\$250 tablet computer for completing each interview. In each session participants completed several questionnaires including demographic data, smoking history, current smoking behaviour including cigarettes per day, and measures of dependence.

**3.4.3. Measures.** Three measures of dependence were administered at Wave 1. The Fagerström Test of Nicotine Dependence (FTND) (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) assesses levels of physical nicotine dependence based on 6 items scored from 0-3 or 0-1. A FTND score is the sum of the six items and scores can be classified as mild [0-3], moderate [4-6] and severe [7-10]. Good test-retest and internal consistency have been demonstrated [ $\alpha = .64$ ] (Pomerleau, Carton, Lutzke, Flessland, & Pomerleau, 1994). The Glover-Nilsson Smoking Behaviour Questionnaire (GNSBQ) (Glover et al., 2005) assesses the behavioural dimension of smoking through patterns of use such as associating smoking with daily activities, as well as the cognitive, social and behavioural effects associated with tobacco dependence. It includes 18 items scored from 0 (“not at all”) to 4 (“extremely so”) and total scores range from 0-72. The GNSBQ has good internal consistency [ $\alpha = .82$ ] and test-retest reliability [ $r = .86$ ], and is significantly correlated with nicotine craving (Rath, Sharma, & Beck, 2013). Finally the Autonomy Over Smoking Scale (AUTOS) (DiFranza, Wellman, Ursprung, & Sabiston, 2009) is comprised of 12 items scored from 0 (“describes me not at all”) to 3 (“describes me very well”). It is comprised of three subscales: 1) Withdrawal Symptoms 2) Psychological Dependence assesse, and 3) Cue-Induced Craving. The AUTOS has excellent internal consistency overall [ $\alpha = .91-.97$ ] and for each of the subscales [Withdrawal Symptoms  $\alpha = .91$ ; Psychological Dependence  $\alpha = .74$ ; Cue-Induced Craving  $\alpha = .77$ ] (DiFranza et al., 2009).

**3.4.4. Statistical Analysis.** Demographic variables (gender, age, income, employment status, education attainment) and smoking information (FTND, AUTOS, GNSBQ, cigarettes per day) were compared between the Māori/Pacific and NZ European/Other groups using analysis of variance (ANOVA) or chi-square analysis as appropriate.

To investigate changes in cigarettes per day at each wave, a mixed model analysis was conducted using IBM SPSS Statistics 22. Mixed model analysis was chosen over repeated measures ANOVA for their greater flexibility to model time effects and correlational patterns between time measurements for longitudinal data, and their ability to handle missing data more appropriately. Plausible covariance-structure models were fitted with and without inclusion of wave as a random effect. The best-fitting mixed model was selected by likelihood ratio comparison tests (Akaike's Information Criterion). The analysis was run with the repeated effect of wave and fixed effects of wave, ethnicity, gender, wave x ethnicity, wave x gender, ethnicity x gender, and wave x ethnicity x gender. Pairwise comparisons (Tukey LSD) were conducted in order to identify where any significant differences occurred within each significant interaction. The relationship between wave and cigarettes per day was also assessed by evaluating linear and quadratic effects for the main effect of wave.

Changes in dependence measures were assessed at Wave 1 and Wave 2. A repeated-measures analysis of variance (RM-ANOVA) was conducted on addiction scores with Wave, ethnicity and gender as factors. Separate analyses were conducted to assess changes in the total scores of the FTND, GNSBQ and AUTOS, and the three subscales of the AUTOS (Withdrawal Symptoms, Psychological Dependence and Cue-Induced Craving).

Table 1. Demographic and smoking dependence information for Māori/Pacific and NZ European/Other groups.

	Māori/Pacific		NZ European/Other	
<i>Gender</i>	%	N	%	N
Male	41	42	48	112
Female	59	61	52	122
<i>Demographic</i>	M	SD	M	SD
Age	36.37	12.32	36.97	13.89
<i>Employment Status</i>	%	N	%	N
Student	4.8	5	20.2	49
Unemployed	26.9	28	18.2	44
Employed	60.6	63	55.0	133
<i>Education Attainment</i>	%	N	%	N
No school qualifications	28.4	29	15.7	36
5 <sup>th</sup> form School Cert/NCEA Level 1	11.8	12	8.7	20
6 <sup>th</sup> form School Cert/NCEA Level 2	5.9	6	10.0	23
University Entrance (NCEA Level 3)	10.8	11	9.6	22
Post-secondary qualification	25.5	26	27.8	64
Undergraduate university degree	8.8	9	11.3	26
Postgraduate university degree	8.8	9	17.0	39
<i>Income</i>	%	N	%	N
<NZ\$20,000	23.8	24	31.1	73
NZ\$20,000 <= x <NZ\$30,000	17.8	18	12.8	30
NZ\$30,000 <= x <NZ\$40,000	12.9	13	8.5	20
NZ\$40,000 <= x <NZ\$50,000	8.9	9	10.2	24
NZ\$50,000 <= x <NZ\$60,000	12.9	13	9.8	23
NZ\$60,000 <= x <NZ\$70,000	6.9	7	6.4	15
>=NZ\$70,000	16.8	17	21.3	50

<i>Smoking Dependence</i>	M	SD	M	SD
FTND	4.08	2.22	4.21	2.18
AUTOS	18.13	8.35	18.61	8.05
GNSBQ	16.63	7.85	17.15	7.86
Cigs/Day	14.71	8.98	14.80	8.47
<i>Changes in Smoking Behaviour</i>	%	N	%	N
Quit by Wave 3	28.95	11	23.89	27
	M	SD	M	SD
Reduction by Wave 3	9.02	9.52	6.10	8.21

### 3.5. Results

Table 1 shows demographic and smoking information. No significant differences were found between the Māori/Pacific and NZ European/Other groups in terms of gender, age, or income. Significant differences were found for occupational status and education attainment. The Māori/Pacific group were significantly less likely to be students [ $\chi^2(3) = 14.310, p < .005, \phi = .203$ ] and had significantly lower education attainment than the NZ European/Other group [ $t(330) = 2.59, p < .005, \phi = .189$ ]. There were no significant differences in smoking dependence between Māori/Pacific and NZ European/Other using the FTND ( $t(344) = .467, p = .641$ ), AUTOS, ( $t(343) = .493, p = .622$ ), GNSBQ ( $t(344) = .569, p = .570$ ) or cigarettes per day ( $t(311) = 0.81, p = .936$ ). There were no differences between the proportions of Māori/Pacific and NZ European/Other smokers that smoked roll-your-own (RYO) versus factory-made (FM) cigarettes [ $\chi^2(1) = .843, p = .358$ ]. Chi-square tests revealed no significant differences between Māori/Pacific versus NZ European/Other in terms of the number of individuals that quit smoking by Wave 2 [ $\chi^2(1) = .988, p = .320$ ] or Wave 3 ( $\chi^2(1) = .386, p = .535$ ).

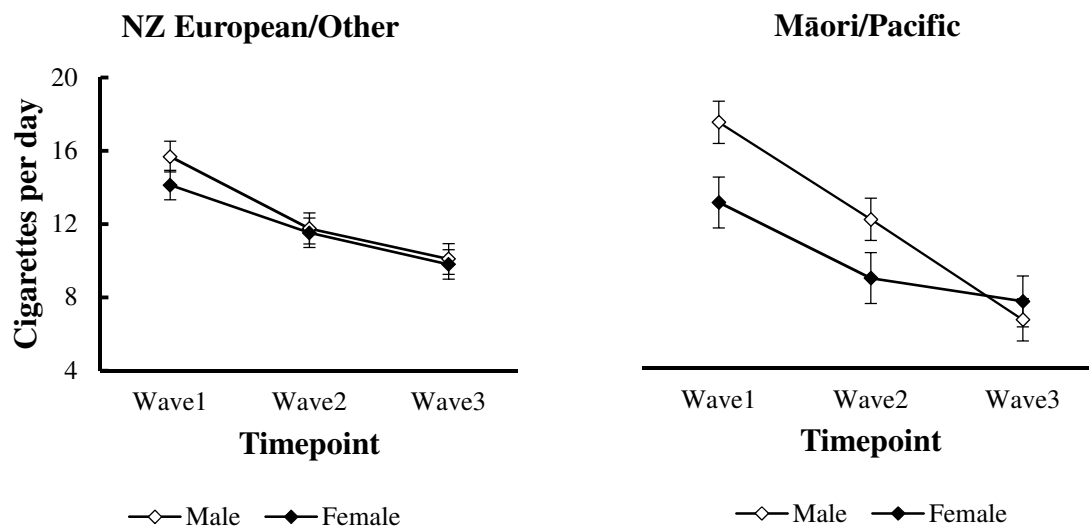


Figure 1. Mean change in cigarettes per day at Waves 1, 2 and 3 for NZ European (left panel) and Māori/Pacific (right panel) groups, plotted separately for males (unfilled diamonds) and females (filled diamonds). Error bars show  $\pm 1$  SE.

Figure 1 shows reported cigarettes per day at Waves 1, 2 and 3. Figure 1 shows that NZ European/Other males and females appeared to smoke similar numbers of cigarettes per day and followed a similar trend in reduction of cigarettes per day from Wave 1 to Wave 3. On the other hand, Māori/Pacific males appeared to smoke more cigarettes per day than Māori/Pacific females at Wave 1 and the reduction in cigarettes per day appeared greater for Māori/Pacific males than females. A mixed model analysis was used to model changes in cigarettes per day at Waves 1, 2 and 3 by ethnicity and gender. Examination of model comparison statistics (AIC) indicated that the data were best modelled using an Unstructured covariance structure that excluded the random effect of wave. There was significant effect of wave [ $F(2, 192.661) = 63.318, p < .001$ ] and polynomial contrasts of wave showed a significant linear effect [ $p < .05$ ] but no quadratic effect [ $p = .91$ ]. This confirms the linear decline in cigarettes per day from Wave 1 to Wave 3 evident in Figure 1. The interaction of



ethnicity and wave was significant [ $F(2, 192.661) = 5.595, p < .005$ ] and pairwise comparisons indicated that Māori/Pacific smokers smoked fewer cigarettes per day than NZ European/Other at Wave 2 [ $p < .05$ ] and Wave 3 [ $p < .05$ ]. There was also a significant interaction of gender and wave [ $F(2, 192.661) = 4.850, p < .01$ ] and pairwise comparisons indicated that males smoked significantly more than females at Wave 1 [ $p < .01$ ]. Finally, there was a significant interaction between ethnicity, gender and wave [ $F(2, 192.661) = 3.451, p < .05$ ]. Pairwise comparisons showed that Māori/Pacific males smoked significantly more than females at Wave 1 [ $p < .013$ ], but there were no other significant differences.

Figure 2 shows mean total scores for the FTND, GNSBQ and AUTOS at Waves 1 and 2. Figure 2 shows an overall trend in which dependence based on the FTND, GNSBQ and AUTOS total scores decreases from Wave 1 to Wave 2. A repeated-measures ANOVA was conducted on the FTND dependence score and found a significant main effect of Wave [ $F(1, 315) = 119.5798, p < .001, \phi = .275$ ] and a significant interaction between gender and ethnicity [ $F(1, 315) = 4.4192, p < .05, \phi = .036$ ]. Post-hoc analyses (Newman-Keuls) revealed that the only significant difference was that Māori/Pacific females had significantly lower dependence using the FTND than NZ European/Other females at both time points. A repeated-measures ANOVA on the GNSBQ dependence score found significant main effects of Wave [ $F(1, 315) = 131.648, p < .001, \phi = .293$ ] and gender [ $F(1, 317) = 5.9232, p < .05, \phi = .018$ ] in which dependence was lower at Wave 2 and higher for females than males. There were no significant interaction effects. A repeated-measures ANOVA on the AUTOS dependence score found a significant main effect of Wave [ $F(1, 314) = 124.438, p < .001, \phi = .28$ ] and no other effects.

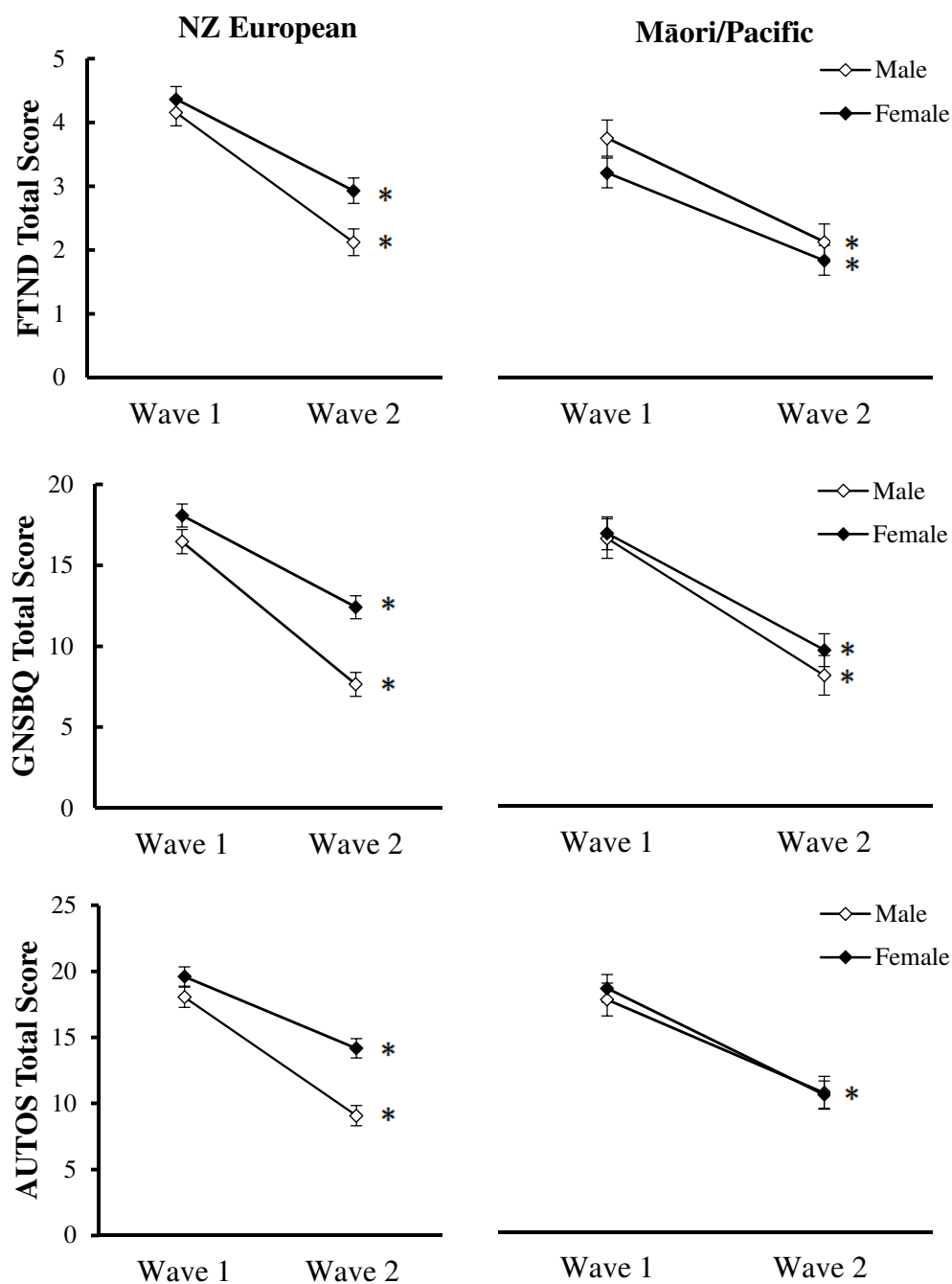


Figure 2. Mean change in total scores for Fagerström Test of Nicotine Dependence (FTND) (top panels), Glover-Nilsson Smoking Behaviour Questionnaire (GNSBQ) (middle panels) and Autonomy Over Smoking Scale (AUTOS) (bottom panels) at Waves 1 and 2 for NZ European (left panel) and Māori/Pacific (right panel) groups, plotted separately for males (unfilled diamonds) and females (filled diamonds). Significant reductions at Wave 2 are indicated by an asterisk (\*). Error bars show  $\pm 1$ SE.

Figure 3 shows scores for each of the subscales of the AUTOS: withdrawal symptoms, psychological dependence and cue-induced craving. Figure 5 appears to show an overall decrease in subscale scores from Wave 1 to Wave 2, most consistently for cue-induced craving. This was confirmed using a repeated-measures ANOVA which found a significant main effect of Wave for cue-induced craving [ $F(1,199) = 20.103$ ,  $p < .001$ ,  $\eta^2 = .092$ ] and no significant interactions. No significant main effects for psychological dependence or withdrawal symptoms, but a significant interaction was found between wave, gender and ethnicity for withdrawal symptoms [ $F(1,199) = 4.1386$ ,  $p < .05$ ,  $\eta^2 = .020$ ]. Post-hoc analysis (Fisher LSD) revealed that the only significant difference was a decrease in withdrawal symptoms from Wave 1 to Wave 2 for NZ European/Other males.

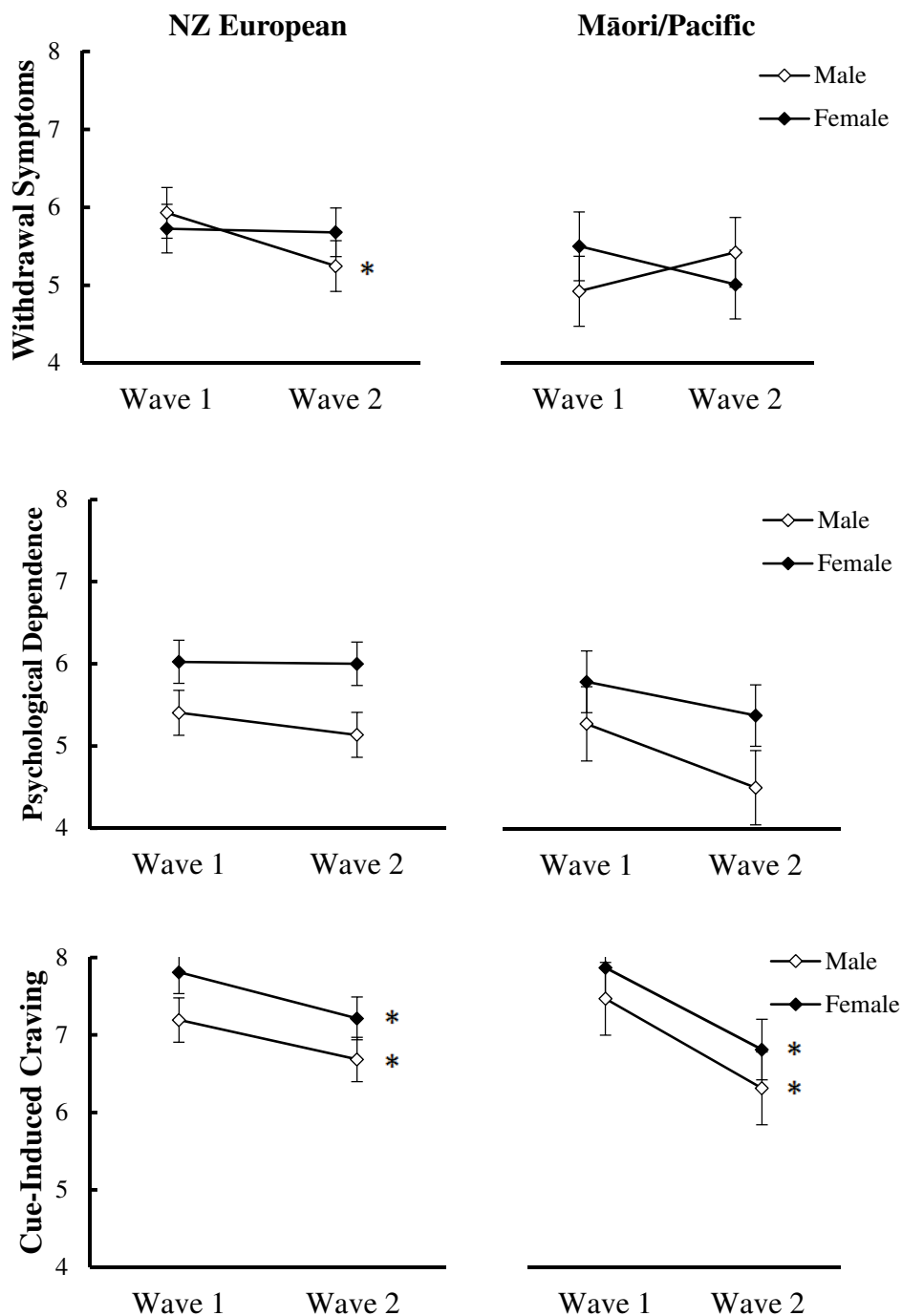


Figure 3. Mean change in Autonomy Over Smoking (AUTOS) subscale scores: Withdrawal Symptoms (top panels), Psychological Dependence (middle panels) and Cue-Induced Craving (bottom panels) at Waves 1 and 2 for NZ European (left panel) and Māori/Pacific(right panel) groups, plotted separately for males (unfilled diamonds) and females (filled diamonds). Significant reductions at Wave 2 are indicated by an asterisk (\*). Error bars show  $\pm 1$ SE.

### 3.6. Discussion

Our goal was to compare measures of smoking dependence and smoking behaviour for Māori/Pacific and NZ European/Other smokers, and to assess whether these groups differed in their response to a series of annual 10% tobacco excise tax increases.

Results showed that there were no significant differences in cigarettes per day or smoking dependence as measured by the FTND, AUTOS or GNSBQ between Māori/Pacific and NZ European/Other smokers at baseline (before the first tax increase). Whereas previous research consistently shows elevated smoking prevalence in Māori and Pacific Islanders (Ministry of Health, 2010b, 2014b, 2014d), to our knowledge there is no existing research that compares psychological measures of nicotine dependence and addiction between Māori/Pacific and NZ European/Other smokers. Our results suggest that, regardless of disparities in smoking prevalence by ethnicity, there were no differences in smoking dependence or the number of cigarettes smoked per day among Māori/Pacific and NZ European/Other smokers prior to the 2012-2014 excise tax increases.

When gender was included in the analysis, we found that overall females had consistently higher addiction levels based on the GNSBQ than males at all time points, while there were no significant gender differences using the FTND or the AUTOS. This indicates that behavioural components of smoking may be more important in female smoking habits than in male smoking habits, while physiological dependence appears to be equally important for males and females. This is partially consistent with a previous study which found that women had significantly higher GNSBQ scores than men while men had significantly higher FTND scores than women (Bohadana et al., 2003), though we found no gender differences using the FTND. There is relatively little research investigating differential reinforcement of smoking behaviour in men and women, however a review of human and animal research suggested that nicotine self-administration and direct reinforcing effects of nicotine (through

discriminative or interoceptive stimuli i.e. physiological changes) appear to be reduced in females relative to males, while non-nicotine stimuli associated with smoking appear to be more reinforcing and influential on smoking behaviour in females (Perkins, Donny, & Caggiula, 1999). It was proposed that females may have reduced discrimination of the physiological (or interoceptive) effects of nicotine unless these effects are paired with contextual or environmental (or exteroceptive) cues; thereby these cues are considered to be more reinforcing of smoking behaviour in women than the physiological effects themselves. This concept has received little research attention. However one recent study found that females showed greater physiological reactivity to nicotine yet reported lower subjective reactivity (DeVito, Herman, Waters, Valentine, & Sofuoglu, 2014). This supports the idea that women have reduced discrimination of the physiological effects of nicotine; however more research is required to understand the relative contributions of nicotine and non-nicotine reinforcers in smoking behaviour in men and women.

When both ethnicity and gender was included in our analyses it was observed that Māori/Pacific females had significantly lower dependence based on the FTND than NZ European/Other females at Waves 1 and 2, while there were no significant differences in behavioural dependence based on the GNSBQ or cigarettes per day. This is particularly interesting given that smoking rates for Māori/Pacific females are one and a half times those of NZ European/Other females (Ministry of Health, 2010b). It may indicate that behavioural, social or cultural influences are particularly important in maintaining smoking behaviour for Māori/Pacific females, while physiological nicotine dependence may have a relatively smaller contribution. This may be partially consistent with previous research which found that among Māori, female smoking rates were more influenced by changes in socioeconomic factors than males (Barnett, Pearce, & Moon, 2005). Similarly, a literature review examined qualitative and quantitative descriptions of self-reported barriers to quitting smoking in

Indigenous groups (not exclusively Māori) and suggested that smoking cessation may exclude an individual from fully participating in their culture or may challenge their family, personal or community relationships (Twyman, Bonevski, Paul, & Bryant, 2014). This is similar to a qualitative review of Māori women's views on smoking cessation initiatives which identified that whānau (extended family) attitudes and behaviour toward smoking, such as friends and whānau members smoking at home, impacted Māori women's smoking behaviour (Fernandez & Wilson, 2008). It appears that Māori/Pacific females may be particularly vulnerable to maintaining smoking behaviour given a combination of a) exposure to increased social acceptance of smoking and environmental smoking cues, and b) increased responsivity to behavioural, social and cultural factors in maintaining smoking behaviour rather than physiological factors. These findings may indicate the importance of holistic smoking cessation interventions for females, particularly Māori/Pacific females that target the home and social environment as well as individual factors.

There were no significant differences in the number of people that quit smoking at Wave 2 and Wave 3 for Māori/Pacific and NZ European/Other smokers (14%). However there were significant differences in changes to smoking behaviour. Overall a linear decline in cigarettes per day was observed from Wave 1 to Wave 3 with a mean reduction in cigarettes per day of 7. Similarly, an overall trend was observed in which psychological dependence decreased from Wave 1 to Wave 2.

There were no significant differences in cigarettes per day between Māori/Pacific smokers and NZ European/Other smokers at Wave 1; however Māori/Pacific smokers smoked significantly fewer cigarettes per day than NZ European/Other smokers at Waves 2 and 3. This suggests that Māori/Pacific smokers were more price sensitive when it came to price increases than NZ European/Other smokers. This effect appeared to be independent of income level, as the groups demonstrated comparable self-reported income. Additionally,

while there were no significant gender differences in cigarettes per day at Waves 1, 2 and 3 for NZ European/Other smokers, Māori/Pacific males smoked significantly more cigarettes per day than Māori/Pacific females at Wave 1 but not at Waves 2 and 3. It is particularly interesting given that Māori/Pacific males did not show any significantly greater reductions in physical and psychological dependence than Māori/Pacific females or NZ European smokers which may suggest that price sensitivity contributes more to cigarette consumption in Māori/Pacific males above and beyond physical and psychological dependence.

We already know that increasing excise tax on tobacco is a cost-effective and powerful smoking intervention. This study adds that two recent tobacco excise tax increases on 1<sup>st</sup> January 2012 and 2013 in New Zealand resulted in 14% of a sample of smokers quitting, a rate that was similar for Māori/Pacific and NZ European/Other smokers, and an average reduction in consumption of 7 cigarettes per day. Few people quit following the tax increases (14%), perhaps reflecting the high tension to quit smoking alongside the chronic relapsing nature of nicotine addiction. However, cessation does not tell the whole story. Notably, Māori/Pacific smokers' consumption of cigarettes per day reduced at a greater rate than NZ European smokers following the two tobacco excise tax increases which may indicate that tax policy is particularly effective at reducing smoking in Māori/Pacific smokers. While reducing consumption of cigarettes may not be associated with the same health benefits as absolute cessation, some evidence suggests that reduction in smoking is associated with greater probability of future quitting (Hughes & Carpenter, 2006) and so these changes may still support the use of excise tax policies in pursuit of New Zealand's dual goals of reducing smoking prevalence and reducing inequalities in smoking and smoking-related outcomes. Additionally, as far as we are aware this study is the first to compare measures of physical and behavioural dependence in males and females, and Māori/Pacific and NZ European smokers in New Zealand. It provides some preliminary



evidence for differential physical and behavioural dependence between males and females in New Zealand, including the particular importance of behavioural dependence in Māori/Pacific females.

While this research renders some interesting findings, some limitations should be acknowledged. We found that Māori/Pacific and NZ European/Other smokers reported similar income levels. However based on the 2013 Census (Statistics New Zealand, 2014a), Māori and Pacific peoples median personal incomes (NZ\$22,500 and NZ\$19,700 respectively) were 78.9% and 69.1% of the national median personal income (NZ\$28,500), and these gaps had increased from 2006-2013. This suggests that our sample may not have been representative of the Māori/Pacific population in New Zealand. Had our sample been more representative, we may have seen different price sensitivities by ethnicity in line with previous research showing that lower income groups are more price sensitive (Wilson et al., 2010). It must also be considered that excise tax increase does not occur in isolation, but is part of a comprehensive tobacco control strategy in New Zealand. Our study does not account for the effects other policies or variables on demand or changes in smoking behaviour over this period.

To conclude, the present study compared measures of smoking dependence and smoking behaviour for Māori/Pacific and NZ European/Other smokers, and assessed whether these groups differed in their response to a series of annual 10% tobacco excise tax increases. The study provided some evidence for differential physical and behavioural dependence between males and females in New Zealand, including the particular importance of behavioural dependence in Māori/Pacific females. We also provided additional support for tobacco excise tax as an effective and powerful smoking intervention and provided some evidence for differential responses to this strategy across ethnic groups in New Zealand. Overall, increasing tobacco excise tax appears to be particularly beneficial in reducing

cigarette consumption in Māori/Pacific smokers, especially Māori/Pacific males. Although this strategy is unlikely to combat inequalities in smoking and smoking-related outcomes alone, it may be considered to be a useful contributor as part of a comprehensive tobacco control strategy.

## CHAPTER 4

### Using a Cigarette Purchase Task to Assess Demand for Tobacco and Nicotine-containing Electronic Cigarettes for New Zealand European and Māori/Pacific Island Smokers

#### 4.1. Preface

The previous chapter demonstrated that Māori/Pacific smokers, especially males, showed the greatest reduction in cigarette consumption in response to excise tax increases, despite low levels of absolute cessation for all groups. However this strategy is unlikely to combat inequalities in smoking prevalence and health outcomes alone, or at the current magnitude of excise tax increases. Due to planned tobacco excise tax increases in New Zealand, cigarette prices will rise at an unprecedented rate until at least 2020. Though economic evidence can infer trends, hypothetical purchase tasks can estimate demand at a broader range of prices in a time- and cost-efficient manner. This chapter uses a CPT to compare measures of demand for tobacco cigarettes at a wide range of prices for New Zealand European and Māori/Pacific smokers.

The previous chapter also highlighted potential differences in smoking dependence between males and females in New Zealand, including elevated behavioural dependence in Māori/Pacific females, indicating that cessation methods and products may need to take into account behavioural and social cues for this high priority group. This chapter also compared first-time subjective effects and cross-price elasticity for a first-generation e-cigarette by ethnicity and gender to assess the potential of e-cigarettes for reducing smoking inequality in New Zealand.

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## 4.2. Abstract

Can nicotine-containing electronic cigarettes (NECs) help to reducing smoking prevalence for Māori and Pacific Island persons in New Zealand? We compared simulated demand for tobacco cigarettes, reactions to first-time use of NECs, and the impact of NEC availability on tobacco demand for New Zealand European and Māori/Pacific Island smokers. New Zealand smokers ( $N=357$ ; 30.1% Māori/Pacific ethnicity and 69.9% NZ European/Other) completed questionnaires and of these 210 consented to attend a session in which they sampled an NEC and completed simulated demand tasks. Māori/Pacific smokers were significantly more price sensitive than NZ European/Other smokers. NECs were partially substitutable for tobacco cigarettes for both New Zealand European and Māori/Pacific smokers, but were rated as more satisfying by Māori/Pacific smokers. Tobacco excise tax increases may be beneficial for discouraging smoking, particularly for Māori/Pacific male smokers, and the availability of NECs at a lower price than tobacco cigarettes may enhance the effects of price increases. NECs may be an attractive vehicle for nicotine replacement therapy and may reduce ethnic disparities in smoking prevalence in New Zealand.

### 4.3. Introduction

Smoking is a major contributor to health inequalities between ethnic groups in New Zealand with consistently poor outcomes for Māori and Pacific Island people (Blakely et al., 2004; Howden-Chapman & Tobias, 2000; Wamala et al., 2006). Smoking prevalence among Māori (35.5%) and Pacific Island groups (22.8%) is elevated compared to New Zealanders of European descent (12.5%) (Ministry of Health, 2016). This increased prevalence hinders Māori and Pacific development aspiration and opportunities through premature death, smoking-related illness and the erosion of economic, social and cultural wellbeing (Māori Affairs Committee, 2010). Māori women have the highest smoking prevalence at 42% compared to Māori men at 34% (Ministry of Health, 2015). Achieving reductions in smoking prevalence among Māori and Pacific peoples, specifically for women, is of vital importance to reduce health inequalities and achieve the national public health goal of a smokefree society (Edwards et al., 2009; Ministry of Health, 2004). Increasing the price of tobacco via excise tax is an integral part of New Zealand's comprehensive tobacco control program and is considered one of the most effective single tobacco control measures worldwide (Chaloupka et al., 2012; Gallet & List, 2003; IARC Working Group, 2011). It is important to consider whether this strategy can help reduce inequalities in smoking prevalence.

Considerable research has used econometric methods to assess how responsive the consumption of cigarettes is to changes in price at a population level (Chaloupka & Warner, 2000; Chaloupka et al., 2012; IARC Working Group, 2011). Meta-analyses of these studies estimate that the average price elasticity of demand for cigarettes is around -0.4, which indicates that a 10% increase in the price of cigarettes would reduce consumption by 4% (Chaloupka & Warner, 2000; Chaloupka et al., 2012; Gallet & List, 2003; IARC Working Group, 2011). Data from New Zealand are consistent with this result, with price elasticity estimates for tobacco from 0.43 - 0.45 (O'Dea et al., 2007; Thomson et al., 2000). However,

it is also important to consider whether responsiveness to price varies across ethnic groups in New Zealand, which cannot be achieved using population-based data. Individual-level data provides a way to compare responsiveness to price across different groups, by administering surveys before and after tobacco excise tax increases.

Two survey studies have compared how Māori, Pacific Island, and New Zealand European smokers respond to tobacco excise tax increases in New Zealand. Walton et al. (2013) found that non-Māori were more likely than Māori to have made a smoking-related behavioural change (quit, tried to quit or cut down on smoking) and that men were more likely to have made a smoking related change than women following a 10% tobacco excise tax increase in 2012. However these differences were not statistically significant. Following a similar tax increase in 2013, Grace et al. (2014) found that Māori and Pacific Island smokers reported significantly greater reductions in cigarettes per day compared to NZ European smokers. The same sample was interviewed again in 2014 following an additional tax rise and Māori and Pacific Island smokers continued to report greater reductions (Tucker et al., 2016). Results also showed that Māori and Pacific Island males reported the greatest reductions in smoking than Māori and Pacific Island females and NZ European smokers. These results suggest that excise tax may be helpful in reducing tobacco-related harm for Māori and Pacific Island smokers in New Zealand and highlight the potential risk for Māori and Pacific Island females who have the highest smoking prevalence and may not benefit from excise tax increases as much as other groups. However, these studies only evaluated the effects of previous price increases. It is important to understand the effects of a wider range of potential price increases on smokers' demand for tobacco, as well as to identify additional policy measures that might help to reduce inequalities for Māori and Pacific Island persons, particularly females.

Simulated demand for cigarettes can be estimated using a Cigarette Purchase Task (CPT), which allows for relatively efficient data collection by asking individuals to estimate their daily cigarette consumption at a broader range of prices than could be assessed in the natural economy (MacKillop et al., 2012). It also produces multiple unique measures in addition to price elasticity, including maximum consumption, price of maximum expenditure, maximum amount spent per day and breakpoint (point at which the individual would quit smoking) which provide a richer understanding of how changes in price would influence the decision to smoke. A number of studies support the validity of using a CPT to derive indices of demand. Robust convergent and divergent validity have been demonstrated in adults (Few et al., 2012; Grace et al., 2014; MacKillop et al., 2008; Murphy et al., 2011), and temporal stability has also been established over a one-week period (Few et al., 2012). Grace et al. (2015a) assessed temporal stability over three months, before and after the 2013 New Zealand tax increase. They found that although the overall results were highly similar, demand after the tax increase was significantly lower for three prices that were immediately above the current market price, indicating that CPT responses are sensitive to tax increases. These studies suggest that the CPT may be a valid and reliable way to measure demand for cigarettes. Grace et al. (2014) tested if CPT demand curves could predict changes in smoking habit following a tax increase. They anticipated that individual measures of demand derived from application of Hursh and Silberberg's (2008) exponential model would predict changes in smoking in response to price increases. Although results showed that smoking decreased for the sample overall after the tax increase, none of the measures derived from Hursh and Silberberg's model (including  $\alpha$ , price elasticity) were significant predictors of changes in smoking. Grace et al. suggested that because  $\alpha$  is based on fits to the full range of prices in the CPT, it may be a less effective predictor than an elasticity measure based on a more limited range near the market price. They showed that a measure of local elasticity, defined

as the regression slope for simulated demand on five prices ranging from NZ\$0.64 to NZ\$0.85 per cigarette, predicted decreases in smoking after the tax increase. This suggests that demand curves and measures derived from the CPT may be used as individual difference variables to predict which smokers will benefit most from tobacco excise tax increases and inform how price could be used to reduce inequalities in smoking prevalence and smoking-related health outcomes.

It is also important to consider how demand for tobacco may change with the availability of alternative products. NECs are a nicotine replacement product that has been shown to be safer than tobacco cigarettes (Farsalinos & Polosa, 2014) and are favourably evaluated by smokers compared to traditional nicotine replacement products (Bullen et al., 2010; Steinberg et al., 2014) and more favourably by females than males (Grace et al., 2015b). Behavioural economic studies of NECs have been used to estimate cross-price elasticity (CPE): a measure of the relative change in demand for NECs when available at a constant price, given a change in price of regular cigarettes. CPE estimates for NECs are significantly positive, indicating that they are at least partially substitutable for regular cigarettes (Grace et al., 2015b; Quisenberry et al., 2016). This suggests that NECs may be used alongside tobacco price policy as a means of reducing tobacco consumption. However, as NECs are a relatively recent development, their efficacy for smoking cessation and long-term risk profile are currently unclear. As a result, regulation has been undertaken with caution in a number of jurisdictions.

In New Zealand, e-cigarettes cannot currently be legally sold if they contain nicotine; however in March 2017 the Ministry of Health proposed legislative change in order to regulate NECs as consumer products (Ministry of Health, 2017). Though this legislation is unlikely to be enacted until at least 2018, it has the potential to complement current tobacco control strategies including price policy to reduce demand for tobacco cigarettes. In this study



we planned to compare simulated demand curves and related measures such as cross-price elasticity for New Zealand European and Māori/Pacific Island smokers using Grace et al.'s (2014) sample. Information regarding ethnic and gender group differences in demand curves could indicate whether price policy could affect smoking-related inequalities in New Zealand. In addition, we compared participants' reactions to first-time use of NECs and their potential impact on tobacco demand.

#### **4.4. Method**

**4.4.1. Participants.** Adult smokers ( $N=357$ ) were recruited by newspaper, community and internet advertising from four major New Zealand cities: Auckland ( $n=72$ ), Wellington ( $n=151$ ), Christchurch ( $n=71$ ) and Dunedin ( $n=63$ ). Participants were required to be daily smokers, over 18 years old, who purchased their own tobacco and had no intention to quit prior to 1 January 2013. Current or past users of NECs, current users of antismoking medication or non-cigarette tobacco, and pregnant/breastfeeding women were excluded. All participants were interviewed in November-December 2012 (Wave 1), and contacted and attended a session in February-March 2013 (Wave 2). Excluded were those who could not be contacted or declined further participation ( $n=131$ ). Also excluded were those who indicated that they had quit smoking by February-March 2013 ( $n=16$ ), leaving a sample size of 210.

Of the sample, 30.1% reported Māori/Pacific ethnicity and 69.9% reported NZ European or other ethnicity. No significant differences were found between Māori/Pacific and NZ European/Other in terms of income, education, number of cigarettes smoked per day or other measures of smoking dependence. See Grace et al. (2014) and Tucker et al. (2016) for detailed demographic data.

All received a NZ\$15 shopping voucher and a chance to win a NZ\$250 tablet computer for each wave. The study was approved by the University of Canterbury and

Victoria University of Wellington Human Ethics Committee, and participants provided written consent.

**4.4.2. Procedure.** Participants completed a pencil-and-paper questionnaire which involved questions about demographics, type of cigarette smoked (factory-made [FM] or roll-your-own [RYO]), packet of tobacco typically purchased (20, 25 or 30 cigarettes per pack for FM; or 30g, 40g or 50g for RYO) and several measures of addiction, and the Cigarette Purchase Task (CPT). Finally, participants were given the opportunity to sample an NEC.

#### **4.4.3. Measures.**

**4.4.3.1. Cigarette Purchase Task.** The CPT is used to measure demand for tobacco over a range of prices. The CPT was adapted from that used by MacKillop et al. (2012) for prices that would be suitable for the New Zealand market. Two versions of the 64-item CPT were used depending on whether the participant indicated that they typically smoked factory-made (FM) or roll-your-own (RYO) tobacco.

For FM smokers, prices per cigarette ranged from NZ\$0.00 to NZ\$5.0 and for RYO smokers, prices were listed in terms of cost per pouch of 30g or 50g of tobacco. To generate prices comparable to those used for the FM CPT, prices for the latter were expressed relative to the current market price for cigs in Nov 2012 (NZ\$0.70/cig) multiplied by the market price per package of 30 or 50g tobacco (NZ\$30 and NZ\$50 at the time) and rounded to whole dollar amounts. Thus minimum non-zero amount and maximum amount were NZ\$2.00 and NZ\$214.00 for 30g; NZ\$4.00 and NZ\$357.00 for 50g. The average current market price was at the same ordinal point among the prices in the scale as the NZ\$0.70/cig on the FM CPT. This way the two questionnaires covered approximately two orders of magnitude, with current market price at the same position, and changes in price relative to current market price were constant across all versions. See Grace et al. (2014) for the instructions and a full description of the range of prices used.

Several analyses were conducted to characterise CPT demand curves. Measures were obtained directly from CPT responses and derived from fits of Koffarnus et al.'s (2015) exponentiated version of Hursh and Silberberg's (2008) demand model using Microsoft Excel Solver . The equation for the exponentiated model is:

$$Q = Q_0 * 10^{k(e^{-\alpha Q_0 C} - 1)}$$

where  $Q$  is the demand at price  $C$ ,  $Q_0$  is maximum consumption (i.e. demand when cigarettes are free),  $k$  is a constant representing the span of the data in  $\log_{10}$  units and  $\alpha$  is elasticity, a fitted parameter which determines how quickly demand falls with increases in price (higher values of  $\alpha$  indicate that demand falls more rapidly with price). Here, we determined  $k$  by subtracting the  $\log_{10}$ -transformed average consumption at the highest price from  $\log_{10}$ -transformed average consumption at the lowest price (giving  $k=1.31$ ). Essential Value (EV) is a definition of value based on sensitivity to price and is inversely proportional to  $\alpha$  (Hursh & Roma, 2016). The formula for EV is:

$$EV = 1/(100 * \alpha * k^{1.5})$$

EV is linearly related to normalised  $P_{\max}$ , the price at which consumption is maximum.  $P_{\max}$  can be obtained from the observed data or calculated using the formula (Hursh & Roma, 2016):

$$P_{\max} = m/(Q_0 * \alpha * k^{1.5}) , \text{ where}$$

$$m = 0.084k + 0.65$$

$O_{\max}$  is the level of response output at  $P_{\max}$ , that is the maximum amount of money spent per day.  $O_{\max}$  can be derived from normalised  $P_{\max}$  or obtained from the observed data.

**4.4.3.2. NEC sampling and questions.** The experimenter explained how the NEC (Safe Cigarette brand) produced a vapour containing nicotine when inhaled and could be puffed similarly to a regular cigarette. The NEC had tobacco extract flavour (no actual tobacco) and was listed as 18 mg/mL nicotine content. On analysis, the Safe Cigarette yielded

13.95 mg/mL nicotine, and 200 hand-drawn puffs at 20 mg of nicotine per puff. After taking several puffs on the NEC, participants were asked to rate both their regular cigarette and the NEC for liking and satisfaction on a single-item 10-point Likert scale (1=don't like at all; 10=like very much). Participants then completed three questions about how many e-cigarettes and regular cigarettes they would purchase per day at different prices. The price of the e-cigarette was listed as NZ\$0.25 per cigarette which consisted of 15 puffs of vapour. The price of regular cigarettes was listed as either NZ\$0.35, NZ\$0.70 or NZ\$1.40 per cigarette. These prices were chosen to correspond approximately to 0.5x, 1x and 2x the market price of cigarettes in New Zealand at the time the study was conducted.

#### **4.5. Results**

Figure 4 shows demand for cigarettes (cigarettes/day) reported on the Cigarette Purchase Task (CPT) for Māori/Pacific (upper panel) and NZ European/Other (lower panel) groups, separately for males and females. For both groups, results were characteristic of demand curves for inelastic commodities with cigarette consumption mostly high and decreasing sharply at relatively high prices, though males appear to report greater demand at all prices. The exponentiated model (Koffarnus, Franck, et al., 2015) provided an adequate description of the average data, accounting for 66% of the variance. Stein et al.'s (2015) algorithm was used to identify nonsystematic data. 14 cases did not meet the trend criterion, 4 cases did not meet the bounce criterion and 2 cases did not meet the reversal criterion. These cases were excluded from demand curve analyses.

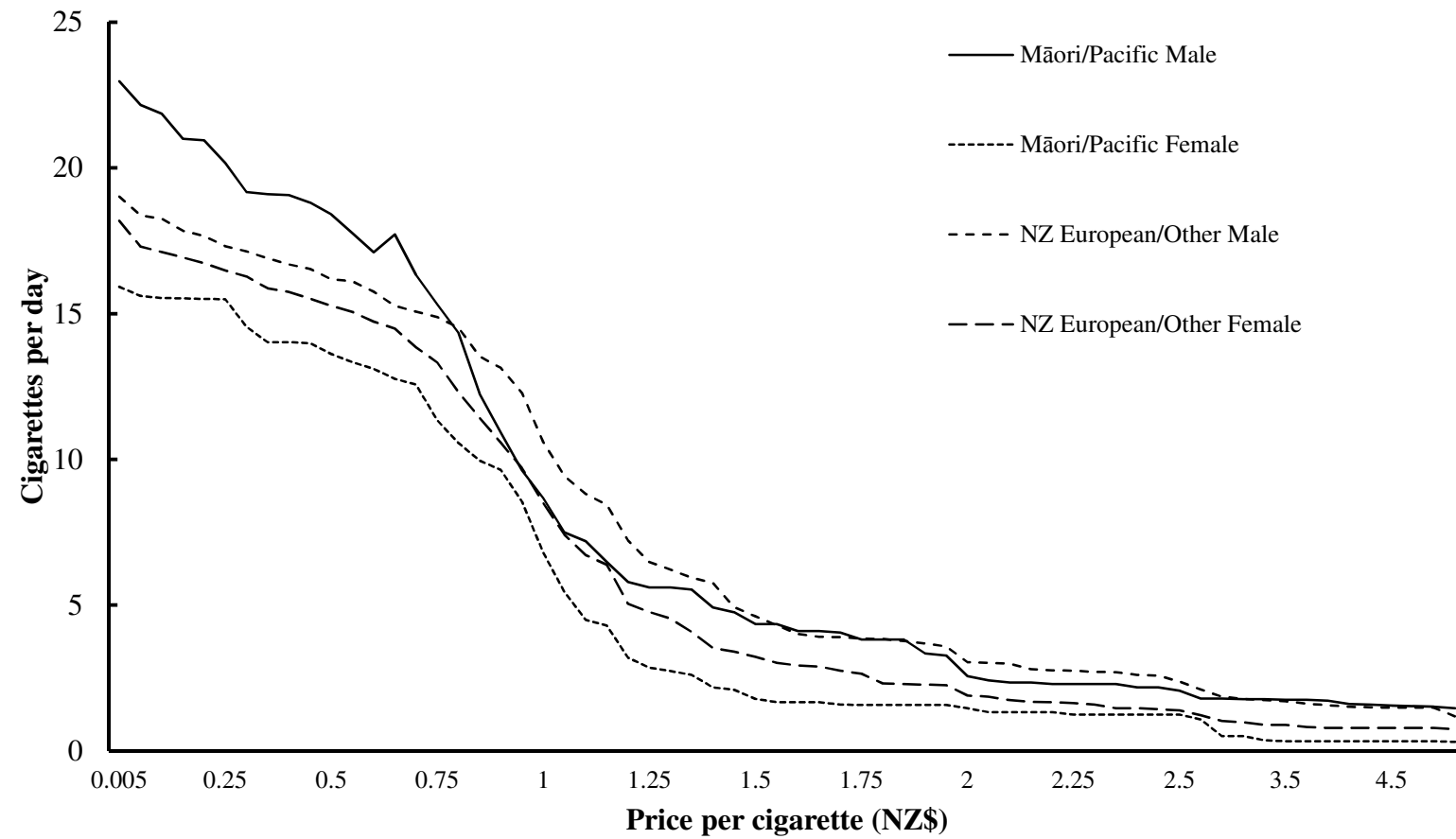


Figure 4. Mean predicted cigarettes per day using the CPT plotted separately for Māori/Pacific males (solid line) and females (dotted line) and NZ/European/Other male (small dashed line) and females (large dashed line).

At prices lower than the current market price in November 2012 (NZ\$0.725/cigarette), the increased demand by males appeared greater for Māori/Pacific males than NZ European/Other males. This was confirmed by a repeated-measures ANOVA which found a significant main effect of price [ $F(1,63) = 418.25, p < .001, \eta^2 = .559$ ] and significant interactions between price and ethnicity [ $F(1,63) = 1.42, p < .05, \eta^2 = .004$ ], price and gender [ $F(1,63) = 1.94, p < .001, \eta^2 = .006$ ], and price, ethnicity and gender [ $F(1,63) = 2.02, p < .001, \eta^2 = .006$ ]. Post hoc analyses [Tukey HSD;  $ps > .05$ ] revealed that there were no significant male-female differences for NZ European/Other smokers. However Māori/Pacific males reported that they would smoke more cigarettes per day than Māori/Pacific females at the lowest price NZ\$0.00 [ $p = .017$ ].

Table 2. Mean scores for measures of demand derived from the CPT.

	Māori/Pacific		NZ European/Other	
	M (SD)		M (SD)	
	Male	Female	Male	Female
EV	0.47 (0.51)	0.36 (0.37)	0.53 (0.79)	0.42 (0.41)
Observed $Q_0$	22.97 <sub>a</sub> (13.57)	15.91 <sub>c</sub> (9.33)	18.84 <sub>b</sub> (13.42)	18.04 <sub>b</sub> (12.27)
Observed $O_{\max}$	20.37 <sub>a</sub> (19.97)	13.21 <sub>c</sub> (7.98)	18.07 <sub>a</sub> (16.95)	15.08 <sub>c</sub> (12.21)
Normalised $O_{\max}$	10.86 (11.71)	8.16 (8.50)	12.20 (18.05)	9.58 (9.34)
Normalised $P_{\max}$	1.69 (1.49)	1.77 (1.93)	2.16 (2.07)	1.91 (1.89)
Breakpoint	1.25 (0.70)	1.43 (0.73)	1.46 (0.72)	1.48 (0.68)

*Note.* Subscripts indicate significantly higher (a) and lower (c) means at  $p < .05$  according to Tukey HSD.

Average measures of demand derived from fits of Koffarnus et al.'s (2015) demand model to CPT data from individual smokers are shown in Table 2. Univariate ANOVAs were conducted on the derived measures. A significant main effect of gender [ $F(1, 333) = 7.048, p < .01, \phi = .021$ ] was found for  $Q_0$ ; males estimated that they would smoke significantly more cigarettes per day than females if cigarettes were free [ $M_s = 19.75$  and  $17.32$  respectively]. There was also a significant gender x ethnicity interaction for  $Q_0$  [ $F(1, 331) = 4.452, p < .05, \phi = .013$ ]. Post-hoc testing (Tukey HSD) indicated that Māori/Pacific males predicted that they would smoke more cigarettes per day if they were free [ $M = 22.97$ ] than Māori/Pacific females [ $M = 15.91, p < .05$ ]; while there were no significant gender differences in  $Q_0$  in the NZ European/Other group [ $M_s = 18.84$  and  $18.04$  respectively]. A significant main effect of gender was found for observed  $O_{\max}$  [ $F(1, 310) = 7.987, p = .005, \phi = .025$ ]; males reporting a higher estimated maximum expenditure per day [ $M = \text{NZ\$}18.57$ ] than females [ $M = \text{NZ\$}14.43$ ]. There were no significant differences in EV, normalised  $O_{\max}$ , normalised  $P_{\max}$ , or breakpoint [ $ps > .05$ ].

When demand for tobacco cigarettes was averaged over the three prices, the availability of NECs produced a 19% decrease in demand for tobacco cigarettes for Māori/Pacific smokers and a 26% decrease for NZ European smokers. A repeated measures ANOVA was conducted on tobacco cigarette demand with NEC availability and price as within-subjects factors and ethnicity as a between-groups factor. There was no difference found for demand between Māori/Pacific and NZ European/Other smokers [ $F(1, 127) = 0.6628, p = .417$ ]. A repeated measures ANOVA was also conducted on NEC demand when tobacco cigarettes were concurrently available at NZ\$0.35, NZ\$0.70 and NZ\$1.40 and, again, no significant differences between Māori/Pacific and NZ European/Other [ $F(1, 205) = 0.7335, p = .393$ ].

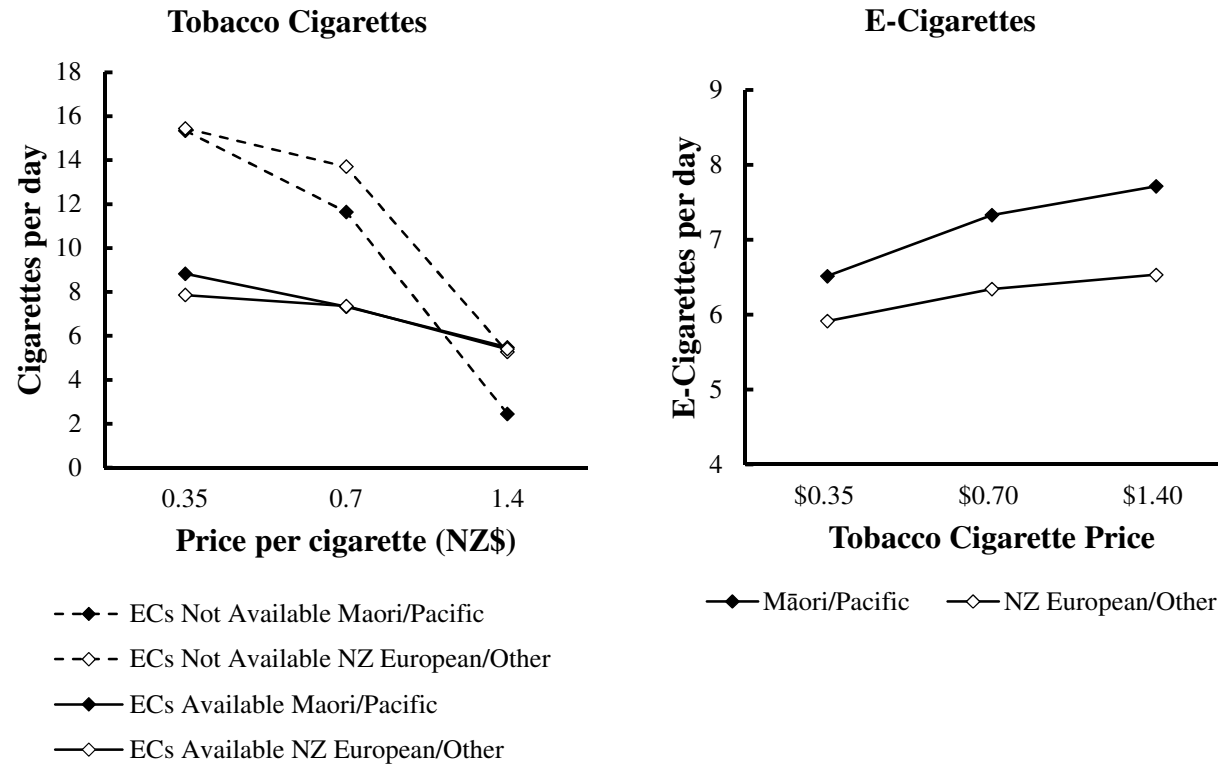


Figure 5. Simulated demand for tobacco cigarettes at prices of NZ\$0.35, NZ\$0.70 and NZ\$1.40/cigarette with e-cigarettes (NECs) at a constant price (NZ\$0.25). The left panel shows intentions to purchase tobacco cigarettes with NECs unavailable (dashed lines) and when NECs were available (solid lines), separately shown for Māori/Pacific (filled diamonds) and NZ European/Other (unfilled diamonds). The right panel shows intentions to purchase NECs (at \$0.25/cigarette = 15 puffs) when they were available with regular cigarettes separately for Māori/Pacific (filled diamonds) and NZ European/Other (unfilled diamonds).



Figure 5 shows demand for cigarettes and NECs at three increasing prices of cigarettes while NECs are available at a constant, discounted price. CPEs were calculated for individual participants as the regression slopes of (log) NEC demand on (log) cigarette price. There were no significant differences in the CPEs for Māori/Pacific smokers and NZ European/Other smokers [ $M_s = .11$  and  $.19$  respectively,  $t(205) = .9155$ ,  $p = .36$ ]. The average CPE for NZ European/Other smokers was significantly greater than zero [ $t(146) = 3.922$ ,  $p < .001$ ] but the average CPE for Māori/Pacific was not [ $t(146) = 1.481$ ,  $p = .14$ ]. CPE was not significantly correlated with any other derived demand measures.

### NEC Ratings

Figure 6 shows the average satisfaction ratings for regular cigarettes and NECs by ethnicity. A repeated-measures ANOVA was carried out with cigarette type (own-brand/NEC), gender and ethnicity as within- and between-group factors. Significant main effects were found for gender [ $F(1,328) = 6.696$ ,  $p < .05$ ,  $\phi = .020$ ] and cigarette type [ $F(1,338) = 21.127$ ,  $p < .001$ ,  $\phi = .060$ ]. The gender x cigarette type [ $F(1,328) = 6.187$ ,  $p < .05$ ,  $\phi = .019$ ] and ethnicity x cigarette type interactions were both significant [ $F(1,328) = 6.967$ ,  $p < .005$ ,  $\phi = .021$ ] but there was no significant gender x ethnicity x cigarette type interaction, indicating that the effects of gender and ethnicity were independent of one another. NEC ratings were significantly greater for Māori/Pacific [ $M = 6.96$ ] than for NZ European/Other smokers [ $M = 5.93$ ] [Tukey HSD,  $p < .005$ ] while there was no difference in own-brand cigarette ratings [ $M_s = 7.35$  and  $7.59$ ,  $p = .821$ ]. The Māori/Pacific group satisfaction ratings for NECs were 94.7% as high as those for regular cigarettes, whereas the NZ European/Other group satisfaction ratings were 78.1% as high for NECs as regular cigarettes.

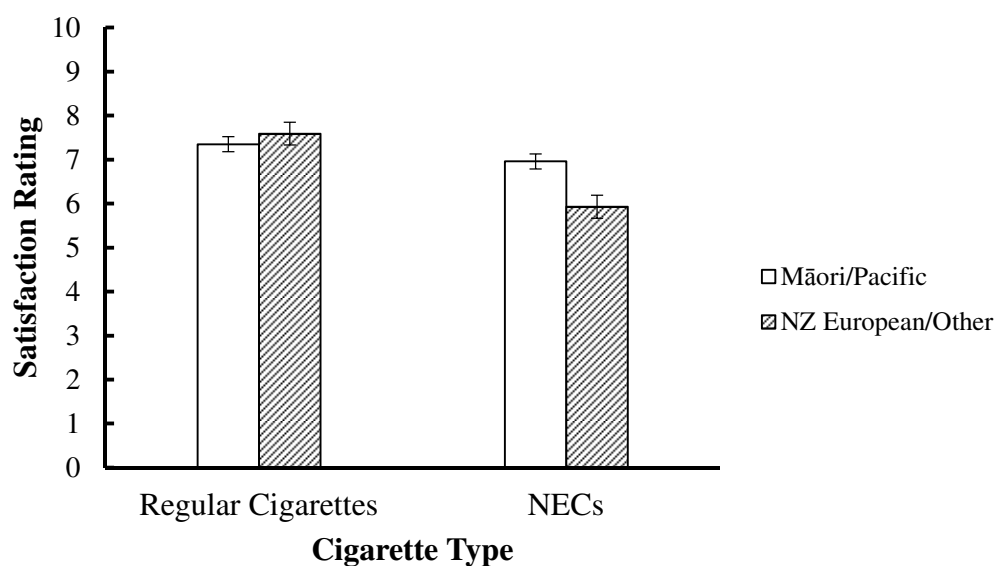


Figure 6. Average satisfaction ratings for regular cigarettes and e-cigarettes, shown separately for Māori/Pacific (unfilled bars) and NZ European/Other (filled bars). Error bars indicate +1 SE.

#### 4.6. Discussion

To our knowledge this is the first study to compare simulated demand generated using a CPT by ethnicity and gender. We aimed to compare demand for cigarettes and NECs, ratings of NECs, and cross-price elasticity of NECs for Māori/Pacific and NZ European/Other males and females using a simulated demand procedure.

Simulated demand curves showed similar trends for Māori/Pacific and NZ European/Other smokers in which demand for cigarettes decreased with price. However some differences were evident. Males demonstrated higher demand for cigarettes at prices lower than the average price per cigarettes at the time sampled (approximately NZD\$0.725), greater maximum consumption and greater maximum expenditure than females. This is consistent with the differences observed in the measures of demand derived from fits of the Koffarnus, Franck, et al. (2015) demand model to the CPT data. Furthermore, Māori/Pacific males showed greater maximum consumption at extremely low prices. These findings indicate that,

for Māori/Pacific male smokers, smoking behaviour may be more limited by price and that if cigarettes were to become more affordable relative to income (as would be the case without repeated annual tobacco excise tax increases), Māori/Pacific males may be at risk of increasing their smoking rates. This finding is consistent with the survey-based data described in Tucker et al. (2016) which found that Māori/Pacific males reduced their smoking rate at a greater rate than Māori/Pacific females following two annual 10% tobacco excise tax increases. Both the survey-based data and simulated demand data suggest that Māori/Pacific males are more price sensitive than Māori/Pacific females and NZ European/Other smokers and sustaining tobacco excise tax increases may be an especially effective strategy for discouraging smoking for these individuals. This raises concern for Māori/Pacific females, who have elevated smoking prevalence, and suggests that other strategies may be required to help Māori/Pacific females reduce their smoking behaviour and ultimately quit smoking.

We found that the availability of e-cigarettes reduced demand for tobacco cigarettes for Māori/Pacific and NZ European/Other smokers. Māori/Pacific smokers responded more particularly favourably to e-cigarettes, however there were no differences in demand for tobacco cigarettes when NECs were concurrently available or cross-price elasticity, and there were no overall correlations between favourability ratings and demand or cross-price elasticity. Reasons for this discrepancy are unclear. While both self-reported subjective effects (e.g. liking, satisfaction, and craving reduction) and elasticity of demand may both be used to infer reinforcement effects, these data are often disparate and may not be correlated with one another or actual smoking behaviour (Shahan et al., 1999). We found no significant relationship between subjective ratings of NECs and cross-price elasticity in this study which suggests that these two measures of the reinforcing efficacy of NECs are independent of one another. While Māori/Pacific smokers responded particularly favourably to NECs, the results

of this study suggest that this is unrelated to their simulated demand for NECs or the extent to which they may consider NECs an alternative to cigarettes.

It is important to interpret our results with caution considering the simplicity of the measures used. Though previous studies have successfully used single-item measures for overall satisfaction for other NRT products (Schneider et al., 2004), a single-item measure of satisfaction is likely to have lower reliability compared to multiple item measures.

Additionally, while hypothetical purchase tasks for cigarettes and alcohol have been shown to correspond with actual behaviour change (Amlung et al., 2012; Lagorio & Madden, 2005; MacKillop, Amlung, Acker, & Stojek, 2010; MacKillop, Miranda, et al., 2010; MacKillop et al., 2016; Madden et al., 2004; Wilson et al., 2016), it is unclear whether CPE as measured using our cross-price task corresponds with the complexity of the actual decision to smoke and actual substitution behaviour. As such, participants may have under- or overestimated the extent to which they would purchase NECs if they were concurrently available with tobacco cigarettes which may explain why ethnic differences were found in satisfaction ratings but not CPE.

Another potential limitation is that participants were asked to rate satisfaction after their first exposure to NECs. It is also unknown whether the high levels of NEC satisfaction, especially for Māori/Pacific smokers, would be maintained long-term. It has been suggested that smokers may have a ‘honeymoon’ period when they first use NECs and their satisfaction may reduce over time (Bullen et al., 2013). This may have impacted participants’ responses to the demand questionnaires and inflated the simulated demand for NECs. However the modest estimated cross-price elasticity for NECs generated in this study appears credible and not over-inflated compared to previous behavioural economic studies (Johnson et al., 2004; O'Connor et al., 2014; Shahan et al., 2000). More research is needed to determine whether the

high satisfaction ratings and demand for NECs can develop into sustained satisfaction, habitual use and eventual cessation.

It must be noted that while we are not aware of any previous research comparing simulated demand for cigarettes in Māori/Pacific and NZ European/Other smokers, research does suggest that lower income groups are more price sensitive (Wilson, 2007; Wilson & Thomson, 2005; Wilson et al., 2010) . In our sample Māori/Pacific and NZ European/Other smokers reported similar income levels; however based on the 2013 Census (Statistics New Zealand, 2014a) Māori and Pacific peoples median person incomes (NZ\$22,500 and NZ\$19,700 respectively) were 78.9% and 69.1% of the national median personal income (NZ\$28,500). Given the lack of significant differences in income between Māori/Pacific and NZ European/Other smokers in our study, our sample may not be representative of the Māori/Pacific population in New Zealand and thus with a more representative sample we may have observed more price sensitivity in Māori/Pacific smokers. Our findings provide some preliminary support for the idea that Māori/Pacific males are more price sensitive than Māori/Pacific females and NZ European/Other smokers and that sustaining tobacco excise tax increases may be beneficial for discouraging smoking for this population.

The current status of NECs in New Zealand is that they cannot be legally sold if they contain nicotine, however in recent years a number of regulatory options have been explored. Wilson et al. (2015) list options ranging from fully liberalised access (free market), increased access as a quit aid or NRT product available in pharmacies, available upon prescription by a registered health professional, available upon prescription from a hospital only pharmacy, to full restraint (complete ban on importing and use). The authors also discuss supplementary policy measures including making it illegal to use NECs in smokefree environments, implementing quality standards, quality criteria for legal sales (age limits, regulated marketing) and price mechanisms to encourage switching. In March 2017 the Ministry of

Health proposed legislative change in order to regulate NECs as consumer products but with similar restrictions to tobacco cigarettes including prohibition of sale to people under the age of 18 years, limits on advertising and vaping in public places, and requirements for product safety (Ministry of Health, 2017). This reflects a relatively liberal regulatory status but with consideration of some of the concerns raised by Wilson et al. (2015). The Ministry of Health (2017) proposal considers excise tax on nicotine e-liquid but acknowledges the complexity of this decision with regard to the unknown risk profile of NECs, the risk of discouraging switching to NECs from tobacco cigarettes, and the limited evidence on the responsiveness of NEC demand to price changes. With annual 10% tobacco excise tax increases scheduled until at least 2020 and the proposed changes to NEC regulation expected to take effect from 2018 at the earliest, it is important to consider whether these policies could reduce demand for tobacco in New Zealand.

Our findings have some implications for the proposed changes to regulation of NECs in New Zealand. Consistent with previous behavioural economic studies (Grace et al., 2015b; Quisenberry et al., 2016), our results support this policy, suggesting that NEC availability could reduce demand for tobacco cigarettes overall. In addition, NECs may be a particularly satisfactory delivery vehicle for NRT for Māori/Pacific smokers. The combination of increased price sensitivity and increased NEC favourability ratings suggests that if NECs become available with an appropriate price differential to regular cigarettes, price sensitive groups including Māori/Pacific male smokers may be encouraged to switch. This supports the idea of differential taxation for NECs relative to tobacco cigarettes (Chaloupka, Swenor, & Warner, 2015; Grace et al., 2015b; Wilson et al., 2015). While their combination with price policy may encourage NEC use for Māori/Pacific males, the similar sensory and behavioural aspects of NECs may encourage their use for Māori/Pacific females, who appear to be less physically dependent on nicotine but more responsive to behavioural, social and cultural cues

(Tucker et al., 2016). As NECs become more available and accessible and as the Smokefree 2025 goal approaches, it will be important to determine whether the positive ratings do translate into increased likelihood of e-cigarette uptake, particularly for Māori/Pacific smokers, whose smoking prevalence remains disproportionately elevated despite comprehensive targeted and population-level tobacco control strategies. In this way, the availability of NECs as a consumer product in New Zealand may reduce ethnic disparities in NRT use and subsequently smoking prevalence.

## CHAPTER 5

### Estimating Demand and Cross-Price Elasticity for Very Low Nicotine Content (VLNC) Cigarettes Using a Simulated Demand Task

#### 5.1. Preface

The previous chapters provided relevant information about the application of price policy in New Zealand and preliminary evidence of the potential for e-cigarettes to complement these policies in the context of achieving the Smokefree2025 goal. The following chapters describe behavioural economic experiments that explore subjective effects and demand for relevant alternative products in more detail. The focus on demand characteristics and cross-price elasticity provides a link between the study of individual responses to alternative products, and how these products may complement price policy as part of a comprehensive tobacco control programme.

VLNC cigarettes provide reduced positive and negative reinforcing effects, and over time could reduce smoking dependence and ultimately smoking behaviour. This chapter uses a CPT to assess demand for both regular and VLNC cigarettes, and a cross-price task asking about purchasing of both products when available concurrently. These two methods simulate demand for the two products when available independently and concurrently, which contributes to the knowledge base on the utility of VLNC cigarettes as part of a nicotine reduction policy and potentially a broader comprehensive nicotine and tobacco policy (Donny et al., 2016).

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Supplementary material is provided at the end of the chapter.



## 5.2. Abstract

Very Low Nicotine Content (VLNC) cigarettes might be useful as part of a tobacco control strategy, but relatively little is known about their acceptability as substitutes for regular cigarettes. We compared subjective effects and demand for regular cigarettes and VLNC cigarettes, and estimated cross-price elasticity for VLNC cigarettes, using simulated demand tasks.

Forty New Zealand smokers sampled a VLNC cigarette and completed Cigarette Purchase Tasks to indicate their demand for regular cigarettes and VLNC cigarettes at a range of prices, and a cross-price task indicating how many regular cigarettes and VLNC cigarettes they would purchase at 0.5x, 1x, and 2x the current market price for regular cigarettes, assuming the price of VLNC cigarettes remained constant. They also rated the subjective effects of the VLNC cigarette and their usual-brand regular cigarettes.

Cross-price elasticity for VLNC cigarettes was estimated as 0.32 and was significantly positive, indicating that VLNC cigarettes are partially substitutable for regular cigarettes. VLNC cigarettes were rated as less satisfying and psychologically rewarding than regular cigarettes, but this was unrelated to demand or substitutability.

VLNC cigarettes are potentially substitutable for regular cigarettes. Their availability may reduce tobacco consumption, nicotine intake and addiction; making it easier for smokers to quit.

### 5.3. Introduction

The reduction of nicotine in tobacco has been proposed as a means to reduce smoking dependence, behaviour and negative health outcomes (Benowitz & Henningfield, 1994, 2013; Donny et al., 2014). One way to achieve this is to make VLNC cigarettes – also known as ‘denicotinized’ cigarettes – available. VLNC cigarettes contain tobacco with substantially less nicotine ( $<0.05\text{mg}$ ), and therefore deliver reduced levels of positively reinforcing effects that maintain smoking behaviour. It is important to distinguish VLNC cigarettes from ‘low yield’ or ‘light’ cigarettes which generate lower yield of nicotine in machine testing due to features such as faster burn time or filter ventilation. Low yield cigarettes are prone to high rates of compensatory smoking which can lead to increased toxicant exposure and health risks (Kozlowski & O'Connor, 2002; National Cancer Institute, 2001). By contrast, VLNC cigarettes are associated with minimal levels or complete absence of compensatory smoking as measured by behavioural change and biomarker exposure relative to regular cigarettes (Benowitz et al., 2012; Benowitz et al., 2007; Benowitz et al., 2006; Donny et al., 2007; Donny & Jones, 2009; Hatsukami et al., 2010).

One way to determine whether VLNC cigarettes can be part of an effective tobacco control policy is to assess their potential as substitutes for regular cigarettes. Ideally, VLNC cigarettes would show comparable subjective favourability to regular cigarettes and similar demand characteristics with price. Subjective favourability may include ratings of quality, satisfaction, craving reduction and withdrawal symptom reduction. Smokers tend to rate VLNC cigarettes as lower quality and less satisfying than their usual brand cigarettes (Benowitz et al., 2006; Donny et al., 2007; Gross et al., 1997; Strasser et al., 2007). However in some cases these effects are minimal and it has been suggested that ratings may be affected by switching from a familiar brand to a novel research cigarette and unrelated to nicotine content (Shahan et al., 1999). For example, Donny et al. (2007) found that switching from

usual brand cigarettes to 0.3mg and 0.05mg cigarettes produced an immediate decrease in positive and increase in negative self-reported effects, regardless of nicotine content. Overall, smokers report that VLNC cigarettes reduce craving and withdrawal symptoms similarly to regular cigarettes (Donny et al., 2007; Gross et al., 1997), and similarly or better than some nicotine replacement products such as nicotine lozenges and patches (Donny & Jones, 2009; Hatsukami, Hertsgaard, et al., 2013; Hatsukami et al., 2010). Because craving and withdrawal symptoms predict subsequent smoking behaviour (Willner, Hardman, & Eaton, 1995), this suggests that despite lower favourability, VLNC cigarettes may be helpful in reducing symptoms of nicotine withdrawal.

Measuring demand and elasticity for VLNC cigarettes is another way of evaluating whether they may help to reduce nicotine intake when available independently or concurrently with regular cigarettes. Demand is the amount purchased at a given price, and elasticity is a measure of sensitivity of demand to changes in price (Hursh, 1980). Several studies have used behavioural responses (e.g. plunger pulls) as an analogue for price. For example, Shahan et al. (1999) found similar levels of demand and elasticity for regular and VLNC cigarettes when available independently. However when both were concurrently available at equal prices there was a strong preference for regular cigarettes. Johnson et al. (2004) examined cross-price elasticity (CPE) of VLNC cigarettes and nicotine gum. CPE is a measure of the relative change in demand for an alternative commodity available at a constant price given a change in the price of an original commodity. It is determined by calculating the slope of the relationship between consumption of the alternative and price of the original in log-log coordinates (Bickel, Degrandpre, & Higgins, 1995). VLNC cigarettes would be considered a substitute for regular cigarettes if they have a positive CPE, meaning their consumption would increase in response to increasing price of regular cigarettes. Johnson et al. (2004) found similar CPEs for VLNC cigarettes and nicotine gum when each

was individually available with regular cigarettes (.19 and .20 respectively) indicating that VLNCs are partially substitutable for regular cigarettes (Bickel, Degrandpre, & Higgins, 1995). This suggests that if the price of regular cigarettes were to increase by 10%, consumption of VLNC cigarettes would increase by 1.9%.

An alternative approach for studying how consumption varies with price is to measure simulated demand in a Cigarette Purchase Task (CPT). In a CPT, smokers estimate how many cigarettes per day they would smoke at a range of hypothetical prices (MacKillop et al., 2008). This allows for relatively efficient data collection based on a broader range of prices than can be assessed in the natural economy or with behavioural analogues of price. The CPT has been used to generate simulated demand curves for regular cigarettes (Few et al., 2012; Grace et al., 2014, 2015a; MacKillop et al., 2008; MacKillop & Tidey, 2011) which conform to an exponential demand model (Hursh & Silberberg, 2008). Although purchase tasks do not measure actual consumption, demand metrics derived from the CPT have demonstrated convergent and discriminant validity (Chase et al., 2013; Few et al., 2012; Grace et al., 2014; MacKillop et al., 2008; MacKillop & Tidey, 2011; Murphy et al., 2011). Prior studies have found substantial overlap between choices for actual and hypothetical commodities (Amlung et al., 2012; MacKillop, Amlung, et al., 2010; MacKillop, Miranda, et al., 2010) (Lagorio & Madden, 2005; MacKillop, Amlung, et al., 2010; Madden et al., 2003; Madden et al., 2004; Wilson et al., 2016), putatively due to the familiarity of the product (e.g. cigarettes for daily smokers) and organisation in discrete, well-understood units (e.g. price in dollars and cigarettes individually or in packs) (MacKillop et al., 2012). Hypothetical purchase tasks have been adapted for a wide range of commodities and can have important policy applications (Roma, Hursh, & Hudja, 2016). The CPT has been used to evaluate the potential effects on bans on menthol flavouring by comparing demand curves for menthol and non-menthol cigarettes (O'Connor, Bansal-Travers, Carter, & Cummings, 2012), and highlighting

‘left-digit effects’ where transitions from one whole-number pack price to the next (e.g. \$4.80-\$5.00) are associated with the largest proportionate decreases in cigarette consumption, and increases in motivation to attempt smoking cessation, (MacKillop et al., 2014; MacKillop et al., 2012; MacKillop et al., 2016). Cross-price elasticity has also been assessed with a simulated demand procedure. Grace, Kivell and Laugesen (2015b) asked smokers to estimate how many regular cigarettes and electronic cigarettes they would consume per day at three increasing prices for regular cigarettes with electronic cigarettes available at a constant, reduced price. Cross-price elasticity for electronic cigarettes was estimated as 0.16 and was significantly positive, indicating that if the price of regular cigarettes were to increase by 10%, consumption of electronic cigarettes would increase by 1.6%.

VLNC cigarettes have the potential to enhance tobacco control efforts by acting as a substitute for regular cigarettes by reducing cravings and withdrawal symptoms, and reducing demand for regular cigarettes. However, it is important to consider how demand for VLNC cigarettes may differ if they are made available concurrently with regular cigarettes but at a discounted price, or if they are the only product available on the market, for example if there is a mandated reduction in nicotine across all brands. Thus in the present study we evaluated demand for VLNC cigarettes when available independently or concurrently with regular cigarettes. We use a Cigarette Purchase Task (CPT) (MacKillop et al., 2008) to obtain simulated demand curves for regular cigarettes and VLNC cigarettes, and also measured changes in simulated demand for VLNC and regular cigarettes when both were concurrently available (Grace et al., 2015b).

## 5.4. Method

**5.4.1. Participants.** 40 adult smokers were recruited by community and internet advertisement in Christchurch. They were required to be daily smokers, at least 18 years old, and not pregnant.

**5.4.2. Procedure.** Participants provided written informed consent. They completed online questionnaires and attended one laboratory session in which they sampled one VLNC cigarette (22<sup>nd</sup> Century Magic brand) and completed questionnaires about the favourability of the VLNC cigarettes and simulated demand for their own brand and the VLNC cigarettes. Participants were required to be abstinent from smoking for 12 hours prior to attending the session which was verified by measuring alveolar carbon monoxide (CO) with a CO monitor. All received a NZ\$10 shopping mall voucher in return. The study was approved by the University of Canterbury Human Ethics Committee.

**5.4.3. Measures.** The online questionnaires included demographic information, smoking history and two dependence measures. The Fagerström Test of Nicotine Dependence (FTND) assesses physical nicotine dependence based on the sum of 6 items scored from 0-3 or 0-1 (Heatherton et al., 1991). Good test-retest reliability and internal consistency have been demonstrated [ $\alpha = .64$ ] (Pomerleau et al., 1994). The Glover-Nilsson Smoking Behaviour Questionnaire (GNSBQ) uses 18 items scored from 0-4 to assess the cognitive, social and behavioural effects associated with tobacco dependence including associating smoking with daily activities and the use of tobacco to meet certain needs (Glover et al., 2005). It has good internal consistency [ $\alpha = .82$ ] and test-retest reliability [ $r = .86$ ], and is significantly correlated with nicotine craving (Rath et al., 2013).

Participants rated their usual brand and the VLNC cigarettes using the modified Cigarette Evaluation Questionnaire (mCEQ) (Rose et al., 2000); a 12-item questionnaire that assesses the reinforcing effects of smoking on three subscales including satisfaction,

psychological reward and aversion, and two single items for enjoyment of respiratory tract sensations and craving reduction. It has good test-retest reliability on all subscales and single items, and the validity of the multidimensional framework was supported (Cappelleri et al., 2007).

Participants completed two forms of the CPT, based on MacKillop et al. (2008), for both their usual brand cigarette and the VLNC cigarette. Participants were asked to estimate their cigarette consumption on a typical day at escalating prices with their existing resources, no access to any other sources of tobacco and no stockpiling. The price range was broad to maximise the changes of attaining a breakpoint, including 20 prices from NZ\$0 to NZ\$25 per cigarette. The prices consisted of: NZ\$0.2 increases from NZ\$0 to NZ\$2, NZ\$1 increases from NZ\$2 to NZ\$5, NZ\$2.50 increases from NZ\$5 to NZ\$20 and a NZ\$5 increase from NZ\$20 to NZ\$25. Factory-made (FM) cigarette smokers were asked to estimate based on price per cigarette and administered the same price schedule as above, whereas roll-your-own (RYO) cigarette smokers were asked to estimate based on price per 30g pouch. Current market price was in the same position on both scales [approximately NZ\$0.80 per FM and NZ\$40 per 30g tobacco package for RYO] and changes in price relative to current market price were constant across both versions of the questionnaire. The CPT for the VLNC cigarettes asked participants to estimate based on price per cigarette regardless of whether they smoked FM or RYO cigarettes.

Several analyses were conducted to characterise CPT demand curves. Measures were obtained directly from CPT responses and derived from fits of Koffarnus et al.'s (Koffarnus, Franck, et al., 2015) exponentiated version of Hursh and Silberberg's (2008) demand model (Koffarnus, Franck, et al., 2015) using Microsoft Excel Solver . The equation for the exponentiated model is:

$$Q = Q_0 * 10^{k(e^{-\alpha Q_0 C} - 1)}$$

where  $Q$  is the demand at price  $C$ ,  $Q_0$  is maximum consumption (i.e. demand when cigarettes are free),  $k$  is a constant representing the span of the data in  $\log_{10}$  units and  $\alpha$  is elasticity, a fitted parameter which determines how quickly demand falls with increases in price (higher values of  $\alpha$  indicate that demand falls more rapidly with price). Here, we determined  $k$  by subtracting the  $\log_{10}$ -transformed average consumption at the highest price from  $\log_{10}$ -transformed average consumption at the lowest price (giving  $k=1.78$ ). Essential Value (EV) is a definition of value based on sensitivity to price and is inversely proportional to  $\alpha$  (Hursh & Roma, 2016). The formula for EV is:

$$EV = 1/(100 * \alpha * k^{1.5})$$

EV is linearly related to normalised  $P_{\max}$ , the price at which consumption is maximum.  $P_{\max}$  can be obtained from the observed data or calculated using the formula (Hursh & Roma, 2016):

$$P_{\max} = m/(Q_0 * \alpha * k^{1.5}) , \text{ where}$$

$$m = 0.084k + 0.65$$

$O_{\max}$  is the level of response output at  $P_{\max}$ , that is the maximum amount of money spent per day.  $O_{\max}$  can be derived from normalised  $P_{\max}$  or obtained from the observed data.

Participants completed an additional cross-price elasticity simulated demand task in which they reported how many VLNC cigarettes and usual brand regular cigarettes they would purchase per day if they were concurrently available at escalating prices of regular cigarette while the price of VLNC cigarettes remained constant. The prices for regular cigarettes were intended to represent approximately 0.5x, 1x and 2x the current market price of cigarettes in New Zealand (NZ\$0.40, NZ\$0.80 and NZ\$1.60), while the price of VLNCs was constant and subsidised (NZ\$0.25).



## 5.5. Results

### 5.5.1. Participant Characteristics. Participant characteristics are shown in Table 3.

The average FTND score was 3.05 [SD=1.95], with no significant differences by gender [ $t(38)=-0.63, p=.52$ ], ethnicity [ $t(34)=-1.90, p=.07$ ], or cigarette type usually smoked [ $t(38)=-1.70, p=.10$ ]. The average level of behavioural dependence for the overall sample was 16.83 [SD = 5.32], which is in the moderate range. Behavioural dependence was significantly higher for females than males with means of 18.61 [SD=4.74] and 14.84 [SD=5.33] respectively [ $t(38)=-2.37, p<.05$ ], but there were no significant differences by ethnicity [ $t(34)=0.09, p=.93$ ] or cigarette type usually smoked [ $t(38)=0.18, p=.86$ ].

Table 3. Participants characteristics (N=40)

Demographic	%	<i>n</i>
Gender		
Male	47.50	19
Female	52.50	21
Ethnicity		
New Zealand European	75	30
Non-European	22.5	9
Cigarette type usually smoked		
Factory-Made	57.50	23
Roll-Your-Own	42.50	17
Demographic	<i>M</i>	<i>SD</i>
Age	24.59	6.64
Smoking Dependence		
FTND	3.05	1.95
GNSBQ	16.82	5.315

*Note:* FTND = Fagerström Test of Nicotine Dependence; GNSBQ = Glover-Nilsson Smoking Behaviour Questionnaire

**5.4.2. Favourability.** Figure 7 shows the subjective favourability ratings based on the four subscales of the mCEQ separately for own brand cigarettes and VLNC cigarettes. Figure 7 shows that participants appeared to rate their own brand cigarettes more favourably than the VLNC cigarette on all four subscales. Participants rated VLNC cigarettes as 62% as satisfying as regular cigarettes ( $M_s = 2.66$  and  $4.28$  respectively), 72% as rewarding as regular cigarettes ( $M_s = 2.81$  and  $3.92$ ), 84% as aversive as regular cigarettes ( $M_s = 1.45$  and  $1.73$ ), and 75% as effective in reducing craving ( $M_s = 3.73$  and  $5.00$  respectively). A repeated-measures multivariate analysis of variance (MANOVA) was conducted with the four subscales (satisfaction, psychological reward, aversion and craving reduction) and cigarette type (own-brand vs. VLNC cigarette) as repeated-measures factor and gender as a between-groups factor. Significant multivariate effects were found for cigarette type [ $F(1,36)=67.038, p<.001, \Lambda=.349$ ], subscale [ $F(1,34)=83.612, \Lambda=.119$ ] and cigarette type x subscale [ $F(3,24)=10.248, \Lambda=.525$ ]. Post-hoc testing (Tukey HSD) showed that own-brand cigarettes were rated higher than VLNC cigarettes for satisfaction, psychological reward, and craving reduction [ $p<.001$ ], but there were no significant differences in aversion [ $p=.77$ ].

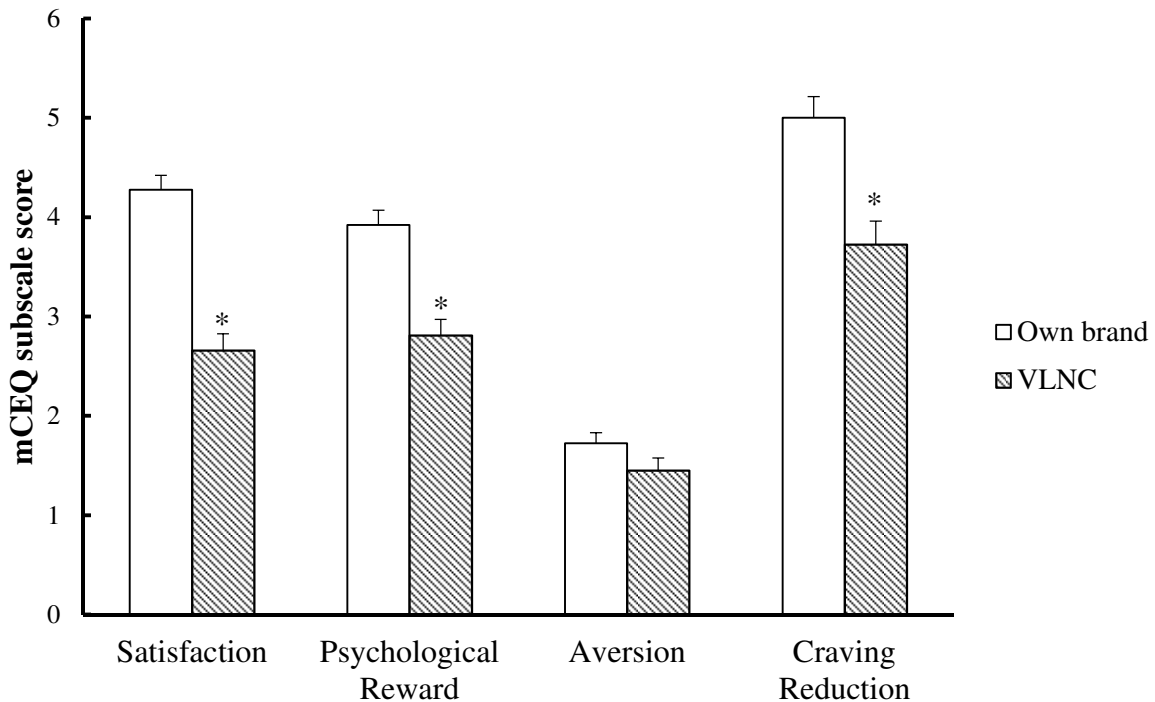


Figure 7. Mean ratings of own brand cigarettes (unfilled bars) and VLNC cigarettes (filled bars) on the four mCEQ subscales. Asterisks (\*) indicate that regular cigarettes are rated significantly higher than VLNC cigarettes. Error bars show 1SE.

**5.4.3. Simulated Demand.** Figure 8 shows demand for own brand and VLNC cigarettes (cigarettes/day) reported on the CPT. The results were characteristic of demand curves for inelastic commodities with cigarette consumption mostly high and decreasing sharply at relatively high prices, though demand for own brand cigarettes appears to be higher, especially at lower prices. The modified exponentiated model (Koffarnus, Franck, et al., 2015) provided a good description of the average data for both own brand cigarettes and VLNC cigarettes, accounting for 94.1% and 95.1% of the variance, respectively. Fits to the individual data were more variable but the model still described results well, accounting for 89.7% of the data for own brand 88.9% for VLNC cigarettes (median values). Stein et al.'s (2015) algorithm was used to identify nonsystematic data. Four cases reported zero

consumption of VLNC cigarettes at all prices for and thus did not meet the trend criterion.

These cases were excluded from the demand curve analysis.

A repeated-measures ANOVA found significant main effects of price [ $F(17,1292)=103.299, p<.001, \eta_p^2=.58$ ] and cigarette type [ $F(1,76)=12.272, p<.001, \eta_p^2=.14$ ], and a significant interaction between price and cigarette type [ $F(17,1292)=5.003, p<.001, \eta_p^2=.06$ ]. Post hoc tests (Tukey HSD) revealed that from prices NZ\$0 to NZ\$1.20 there was significantly higher demand for own brand cigarettes than for VLNC cigarettes, however at prices of NZ\$2 or higher there were no significant differences in demand for own brand or VLNC cigarettes. There was a significant interaction between cigarette type usually smoked (FM versus RYO) and price [ $F(17,1292)=4.196, p<.001, \eta_p^2=.05$ ] but no other significant interactions. Post-hoc tests (Tukey HSD) revealed that RYO smokers reported higher demand for cigarettes at very low prices (NZ\$0 – NZ\$.20) than FM smokers, but no significant differences at prices NZ\$.40 or higher. Gender did not have a significant effect on demand [ $F(1,76)=0.266, p=0.61$ ]. Prices of NZ\$20 and NZ\$25 per cigarette were excluded from the analysis as there was no variance; all participants reported zero consumption at these prices

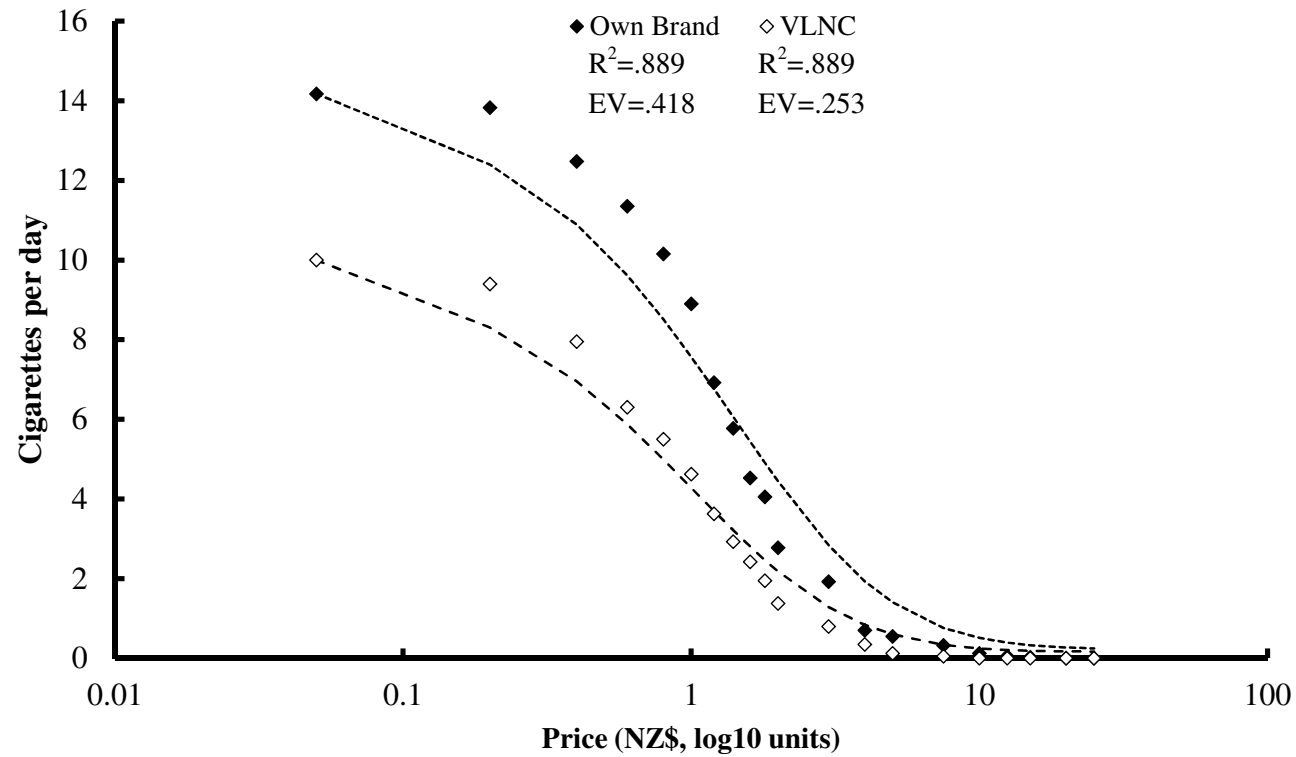


Figure 8. Simulated demand for own brand cigarettes (filled diamonds) and VLNC cigarettes (unfilled diamonds) using the CPT plotted on logarithmic axes. The dashed lines indicate fits of the modified exponentiated model for each cigarette type.

Table 4 shows means, results of repeated-measures ANOVAs and correlations for demand metrics derived from the CPT and the modified exponentiated model (Koffarnus, Franck, et al., 2015) for own brand cigarettes and VLNC cigarettes. As anticipated, strong correlations were found between observed and derived  $Q_0$  ( $r=0.99$  for own brand cigarettes;  $r=1.00$  for VLNC cigarettes) and  $O_{\max}$  ( $r=0.94$  for own brand cigarettes;  $r=0.98$  for VLNC cigarettes) scores. Repeated-measures ANOVAs confirmed that almost all demand metrics were significantly higher for own brand cigarettes than VLNC cigarettes including: EV [ $M_s = 0.418$  and  $0.253$  respectively;  $F(1,31)=7.719$ ,  $p<.01$ ,  $\eta_p^2=.20$ ], observed  $Q_0$  [ $M_s = 14.175$  and  $10.368$ ;  $F(1,34)=13.372$ ,  $p<.001$ ,  $\eta_p^2=.27$ ], derived  $Q_0$  [ $M_s = 16.306$  and  $11.345$ ;  $F(1,36)=13.647$ ,  $p<.001$ ,  $\eta_p^2=.27$ ], observed  $O_{\max}$  [ $M_s = 12.960$  and  $7.640$ ;  $F(1,31)=11.011$ ,  $p<.005$ ,  $\eta_p^2=.26$ ], derived  $O_{\max}$  [ $M_s = 10.365$  and  $6.260$ ;  $F(1,31)=67.719$ ,  $p<.01$ ,  $\eta_p^2=.20$ ], and BP [ $M_s = 4.703$  and  $2.747$ ;  $F(1,36)=6.545$ ,  $p<.05$ ,  $\eta_p^2=.15$ ]. There was no significant difference in  $P_{\max}$  [ $M_s = 2.620$  and  $1.894$ ;  $F(1,31)=3.412$ ,  $p=.74$ ] for the two cigarette types. A significant interaction was found between type of cigarette usually smoked and cigarette type sampled for BP [ $F(1,34)=5.576$ ,  $p<.05$ ,  $\eta_p^2=.15$ ]. Post hoc analysis (Tukey HSD) revealed that FM smokers reported a higher breakpoint for their own brand cigarettes [ $M = 6.552$ ] than RYO [ $M = 2.200$ ], but there were no significant differences in breakpoints for VLNCs [ $M_s = 3.065$  and  $2.029$ ]. Additionally, FM smokers had significantly higher breakpoints for their own brand cigarettes [ $M = 6.552$ ] than VLNC cigarettes [ $M = 3.065$ ], but not RYO smokers [ $M_s = 2.2000$  and  $2.029$ ].

Table 4. Mean scores and correlation coefficients for measures of demand derived directly from the CPT and from fits of Koffarnus et al.'s (2015) exponentiated model shown separately for own brand and VLNC cigarettes.

M (SD)								
Own Brand		1.	2.	3.	4.	5.	6.	7.
1. Essential Value	0.418 (0.291)	-						
2. Observed $Q_0$	14.175 (9.719)	0.45*	-					
3. Derived $Q_0$	16.306 (10.852)	0.48*	0.99*	-				
4. Observed $O_{\max}$	12.960 (8.848)	0.94*	0.57*	0.60*	-			
5. Derived $O_{\max}$	10.365 (7.214)	1.00*	0.45*	0.48*	0.94*	-		
6. $P_{\max}$	2.620 (1.844)	0.65*	-0.22	-0.20	0.51*	0.65*	-	
7. Breakpoint	4.703 (4.429)	0.31*	-0.13	-0.16	0.27	0.31*	0.46*	-
VLNC		1.	2.	3.	4.	5.	6.	7.
1. Essential Value	0.253 (0.217)**	-						
2. Observed $Q_0$	7.640 (5.440)***	0.42*	-					

3. Derived Q <sub>0</sub>	6.260 (5.372)***	0.46*	1.00*	-				
4. Observed O <sub>max</sub>	12.955 (8.847)**	0.98*	0.50*	0.55*	-			
5. Derived O <sub>max</sub>	10.368 (8.296)**	1.00*	0.42*	0.46*	0.98*	-		
6. P <sub>max</sub>	1.894 (1.434)	0.77*	-0.13	-0.10	0.67*	0.778	-	
7. Breakpoint	2.747 (2.583)*	0.49*	0.00	-0.02	0.40*	0.49*	0.58*	-

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*Note:* Asterisks (\*) indicate significant differences between VLNC cigarettes and regular cigarettes, or significant correlations; \*p<.05, \*\*p<.01, \*\*\*p<.001



Figure 9 shows that demand for regular cigarettes decreased with increases in price, while demand for VLNC cigarettes (available at a constant, discounted price) increased. Cross-price elasticities (CPE) were calculated for individual participants as the regression slopes of (log) VLNC demand on (log) tobacco cigarette price. The mean CPE was 0.32 [95%CI=0.578, 0.907] which was significantly greater than zero [ $t(39)=2.886$ ,  $p<.01$ ,  $d=.92$ ]. The positive value indicates that VLNC cigarettes are partially substitutable for regular cigarettes, such that if the price of regular cigarettes increased by 10%, consumption of VLNC cigarettes would increase by 3.2%. However, a positive CPE was only found for 25% of the sample, and the median CPE was 0. This indicates that, for the majority of the sample, demand for VLNC cigarettes did not increase with increasing price of regular cigarettes. Demand for regular cigarettes on the cross price task was 13.63% lower than average demand at the same three prices on the CPT (where only usual brand was available).

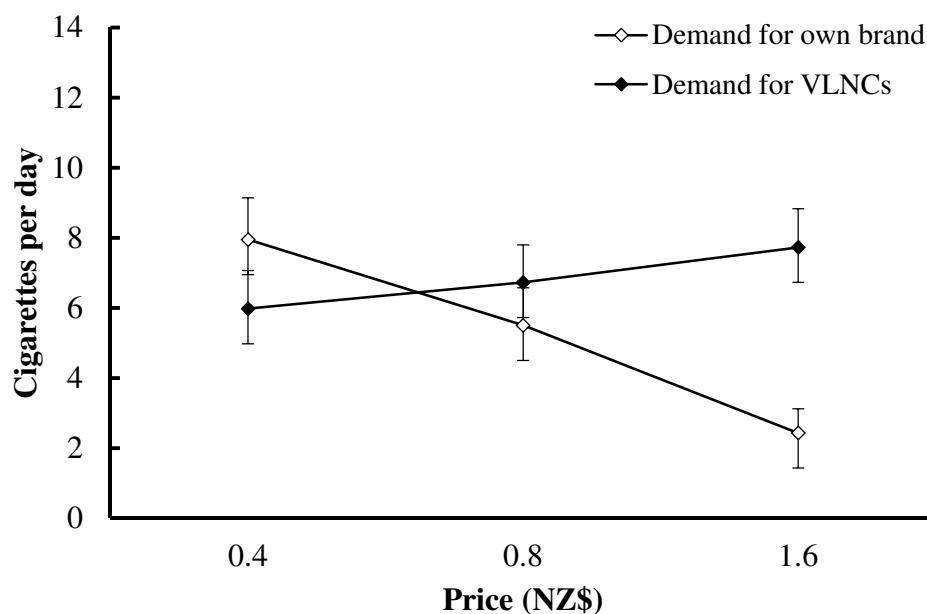


Figure 9. Simulated demand for Very Low Nicotine Content (VLNC) cigarettes and regular cigarettes at three increasing prices of regular cigarette while VLNC cigarettes are available at a constant, discounted price. Error bars show  $\pm 1$ SE.

Correlation analyses were conducted between smoking dependence scores (FTND and GNSBQ), the mCEQ subscales (reward, satisfaction and craving reduction) for both own brand and VLNC cigarettes, demand metrics (EV, normalised  $O_{\max}$ , normalised  $P_{\max}$ , derived  $Q_0$  and breakpoint) for both own brand and VLNC cigarettes, CPE and average demand for VLNC cigarettes across all three prices on the cross-price task. A summary of these analyses is included as Supplemental Material. Smoking dependence (FTND) was significantly positively associated with several demand metrics for own brand cigarettes (EV  $r=0.58$ ; normalised  $O_{\max}$   $r=0.58$ ; normalised  $P_{\max}$   $r=0.34$ , and derived  $Q_0$   $r=0.57$ ) and with  $Q_0$  for VLNC cigarettes ( $r=0.43$ ). However, smoking dependence (FTND) was significantly negatively correlated with satisfaction ( $r=-0.46$ ), craving reduction ( $r=-0.37$ ) for VLNC cigarettes. CPE was significantly positively associated with several demand metrics for VLNC cigarettes (EV  $r=0.39$ ; normalised  $O_{\max}$   $r=0.39$ ; normalised  $P_{\max}$   $r=0.42$ ) but not with any VLNC mCEQ favourability subscales.

## 5.6. Discussion

VLNC cigarettes were rated as less satisfying and less psychologically rewarding than own-brand regular cigarettes, consistent with previous research (Benowitz et al., 2006; Donny et al., 2007; Gross et al., 1997; Strasser et al., 2007). It has been suggested that negative responses to research cigarettes may be attributed to the fact that they are novel stimuli rather than the nicotine content per se (Donny et al., 2007). However in our study the participants sampled only one VLNC cigarette after a period of 12 hours abstinence, thus it is likely that nicotine withdrawal symptoms may have played a role. Although responses to the satisfaction subscale may have been more related to the novel nature of the cigarettes (items include enjoyment, satisfaction and taste), the psychological reward subscale appears to be more related to the alleviation of nicotine withdrawal symptoms (items include feeling more calm, more awake, less irritable, improved concentration and reduced hunger for food). As

participants rated satisfaction and psychological reward at comparable levels for VLNC and regular cigarettes, the relative effects of the novel nature of the VLNC cigarette and the reduced nicotine content remain unclear. Participants also rated greater craving reductions for regular cigarettes than VLNC cigarettes, though both were rated highly. This is different from previous studies which have suggested that while participants rate VLNCs as less favourable than regular cigarettes, they reduce their craving, withdrawal symptoms and smoking behaviour at a similar rate (Donny et al., 2007; Donny & Jones, 2009; Gross et al., 1997; Hatsukami, Hertsgaard, et al., 2013; Hatsukami et al., 2010). Aversion was rated very low for both regular and VLNC cigarettes suggesting that although VLNCs were rated less satisfying and rewarding than regular cigarettes, participants did not experience any aversive effects. Though they may have limited satisfying and rewarding properties, this was not correlated with demand or substitutability in this study.

The demand curves produced by the CPT were similar for regular cigarettes and VLNC cigarettes, with patterns of decreasing demand with increasing price. Although demand for regular cigarettes was higher at relatively lower prices (up to \$2 per cigarette), at higher prices there was no difference in demand for regular and VLNC cigarettes. At the other end of the scale, participants reported greater demand for regular cigarettes than VLNC cigarettes when the products were free. It is unclear why demand intensity is significantly lower for VLNC cigarettes. As they contain significantly less nicotine than regular cigarettes it would be anticipated that consumption would be higher in order to achieve optimal levels of reinforcement. This may suggest that preference and favourability are more important factors in determining consumption than optimal nicotine intake at lower, more affordable prices than at higher prices. However it is possible that the single use of the VLNCs may have been insufficient for participants to make informed choices on the CPT, and as such this design may not have supported an accurate assessment of demand and CPE. Nonetheless

there may be important policy implications based on the demand data. The higher maximum amount of money spent per day ( $O_{\max}$ ) for regular cigarettes than VLNC cigarettes indicates that if VLNC cigarettes were available alongside regular cigarettes, even if at the same prices, smokers may reduce their expenditure on cigarettes. Breakpoint was also higher for regular cigarettes than VLNC cigarettes, indicating that smokers would quit at lower prices if VLNC cigarettes replaced regular cigarettes. These differences could have implications for low-income groups, for whom smoking prevalence is elevated (Ministry of Health, 2014a). VLNCs may have the potential to reduce tobacco consumption and therefore expenditure, and may also mean that smokers would quit at lower prices which could have positive health and financial implications.

The positive CPE [0.32] indicates that VLNCs are partially substitutable for regular cigarettes. This supports the utility of VLNC cigarettes, especially alongside the finding that on average demand for regular cigarettes was reduced by 13.63% if VLNC cigarettes were available. Our VLNC CPE was slightly higher than the estimate obtained using behavioural procedures (Johnson et al., 2004). It was also higher than the estimates generated for nicotine gum using behavioural procedures (Johnson et al., 2004; Shahan et al., 2000) and regular electronic cigarettes using a simulated demand procedure (Grace et al., 2015b). Reasons for this discrepancy are unclear. From a behavioural economic perspective, a reinforcer serves as a substitute because it shares a common function with the original reinforcer (Bickel, Degrandpre, & Higgins, 1995). It is possible that the behavioural, motor and sensory functions shared by regular cigarettes and VLNC cigarettes are more instrumental in smoking behaviour than the shared function of nicotine withdrawal relief targeted by nicotine gum and regular electronic cigarettes.

We found that higher nicotine dependence was associated with greater intensity of demand and more inelastic demand for regular cigarettes. These results were as expected and

suggest that smokers that are more dependent on nicotine are less likely to change their smoking behaviour in response to increases in the price of regular cigarettes. Greater dependence was also associated with lower satisfaction and craving reduction ratings for VLNC cigarettes. Again, this is to be expected as people with higher nicotine dependence are less likely to attain their optimal level of nicotine from the minimal levels available in VLNCs. It suggests that VLNC cigarettes may be less appealing for smokers that are more dependent on nicotine. Interestingly, CPE was associated with greater demand for VLNC cigarettes but was not associated with nicotine dependence, any demand indices for regular cigarettes or favourability ratings for either type of cigarettes. This suggests that the relatively negative favourability ratings of VLNCs did not impact how likely people would be to substitute them for regular cigarettes. Ratings of other perceptions and expectations of VLNC cigarettes may provide insight in to what factors are associated with CPE, such as expected health benefits and their ability to help people quit smoking.

Some limitations of the present study should be acknowledged. First, the sample size was relatively small, and several cases needed to be excluded from the VLNC analysis due to poor model fit. Second, we excluded four cases from the VLNC model fit where zero consumption was reported at all prices. It must be acknowledged that zero reported consumption is important information representing extremely low valuation of VLNCs for some individuals. As such the demand estimates for VLNC cigarettes may be somewhat inflated due to the exclusion of these cases. Third, it is not clear how accurately measures of simulated demand collected under controlled conditions correspond with actual behaviour. However previous research suggests that choices in hypothetical purchase tasks correspond with actual behaviour (Amlung et al., 2012; Lagorio & Madden, 2005; MacKillop, Amlung, et al., 2010; MacKillop, Miranda, et al., 2010; Madden et al., 2003; Madden et al., 2004; Wilson et al., 2016) and our estimates of elasticity for VLNC cigarettes produced extremely

good fits with the exponential model (Hursh & Silberberg, 2008) and were comparable with elasticity estimates for regular cigarettes in this study and in previous studies (Gallet & List, 2003; Grace et al., 2014; MacKillop et al., 2008). Additionally, the predictive validity of elasticity derived from CPT data has been demonstrated following a tobacco excise tax increase (Grace et al., 2014) which suggests that these procedures provide important information regarding the responsiveness of demand for VLNC cigarettes with changing price. Another limitation is the use of general price rather than unit price, that is, price per ml of nicotine. Unit price might help to clarify the mechanism underpinning differences in the demand curves and demand metrics for VLNC cigarettes; whether it is the significantly increased cost per mg of nicotine or non-nicotine factors. Finally, the cross-price task was comprised of a limited range and density of prices for tobacco cigarettes, and as such the CPE may not accurately estimate the shape of the function. Hursh and Roma (2016) propose an extension of the exponential equation for fitting CPE:

$$Q_B = \log(Q_{alone}) + Ie^{-\beta * C_A}$$

where  $Q_{alone}$  is the level of demand for the constant-price commodity B (VLNC cigarettes) at infinite price (C) for commodity A (regular cigarettes),  $I$  is the interaction constant,  $\beta$  is the sensitivity of the commodity B to the price of commodity A and  $C_A$  is the price of commodity A (Hursh & Roma, 2016). This potentially provides a more accurate estimate of CPE but requires consumption to be determined at a greater number of prices than the current study. However the prices we used (0.5x, 1x and 2x current market price) encompassed a relatively realistic range to obtain an estimate of the slope. The task has also been used in a previous study to obtain a CPE estimate for electronic cigarettes (Grace et al., 2015b, 2015c) and yielded similar CPE estimates to those obtained in behavioural economic studies with

nicotine gum and denicotinized cigarettes which used eight prices (Johnson et al., 2004; Shahan et al., 2000).

We found similar demand curves and fits with the exponentiated model (Koffarnus, Franck, et al., 2015) for regular and VLNC cigarettes which suggests that simulated demand procedures may be effectively used for alternative tobacco products. We also found similar, though slightly higher, CPE estimates to those generated using behavioural procedures using the simulated demand procedure (Johnson & Bickel, 2003; Johnson et al., 2004; Shahan et al., 2000). Although results should be interpreted cautiously, simulated demand procedures are a time- and cost-efficient way in which to generate quantitative and graphical estimates of demand, elasticity and cross-price elasticity at a far wider range of prices than can be observed in the general market.

There are multiple ways in which VLNC cigarettes may contribute to a nicotine reduction policy. One strategy would be to mandate that all cigarette brands gradually reduce their nicotine content to non-addictive levels ( $<0.05\text{mg}$ ). Another, likely more realistic, strategy would be to make VLNC cigarettes available at a lower prices than regular cigarettes. Our results suggest that VLNC cigarettes might serve as a more affordable substitute for regular cigarettes by increasing consumption of non-addictive cigarettes and reducing nicotine intake. It would be important to complement VLNCs with other evidence-based policies, such as continuing to increase the price of cigarettes, and considering the potential of novel approaches such as alternative nicotine delivery systems (e.g. electronic cigarettes) also at relatively lower prices, as part of a comprehensive tobacco control strategy.

### 5.7. Supplementary Material 1. Table S1. Correlations between dependence measures, mCEQ subscale scores and derived demand measures

shown separately for regular and VLNC cigarettes

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10	11.	12.	13.	14.	15.	16.	17.	18.	19.
1. FTND	-																		
2. GNSBQ	.33	-																	
Own Brand																			
3. Satisfaction	-.18	.08	-																
4. Reward	.27	.64*	.17	-															
5. Craving ↓	-.21	.12	.19	.13	-														
6. EV	.58*	.15	.00	.17	-.13	-													
7. nm O <sub>max</sub>	.58*	.15	.00	.17	-.13	1.00*	-												
8. nm P <sub>max</sub>	.34*	.37*	.40*	.36*	.14	.62*	.62*	-											
9. Derived Q <sub>0</sub>	.57*	-.08	-.38*	-.09	-.25	.49*	.49*	-.23	-										
10. Breakpoint	.03	.47*	.29	.41*	.13	.22	.22	.54*	-.28	-									
VLNC																			
11. Satisfaction	-.46*	-.17	.40*	.12	.28	-.36*	-.36*	-.18	-.34*	.13	-								
12. Reward	-.16	.27	.16	.52*	-.02	-.22	-.22	-.10	-.27	.29	.53*	-							
13. Craving ↓	-.37*	-.30	.22	-.21	.26	-.29	-.29	-.12	-.37*	-.16	.63*	.30	-						
14. EV	.28	-.07	-.08	.14	.39*	.18	.18	.00	.25	.00	.08	.02	.15	-					
15. nm O <sub>max</sub>	.28	-.07	-.08	.14	.39*	.18	.18	.00	.25	.00	.08	.02	.15	1.00*	-				
16. nm P <sub>max</sub>	.12	-.03	-.01	.08	.30	.14	.14	.17	-.12	.10	-.04	.04	.16	.77*	.77*	-			



17. Derived $Q_0$	.43*	-.01	-.18	.04	-.02	.21	.21	-.23	.74*	-.15	.00	-.08	-.19	.46*	.46*	-.10	-		
18. Breakpoint	-.04	-.04	.03	-.05	.12	-.08	-.08	.06	-.26	.40*	.16	.14	.18	.49*	.49*	.58*	-.02	-	
19. CPE	.03	-.33	-.18	-.23	.10	-.14	-.14	-.24	.12	-.31	-.07	-.23	.10	.39*	.39*	.42*	-.08	.05	-

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Note: Asterisks (\*) indicate significant correlations; FTND = Fagerström Test of Nicotine Dependence, GNSBQ = Glover-Nilsson Smoking

Behaviour Questionnaire, Craving ↓ = Craving reduction, EV = Essential Value, nm  $O_{\max}$  = Normalised  $O_{\max}$ , nm  $P_{\max}$  = Normalised  $P_{\max}$ .

## CHAPTER 6

### Subjective Effects and Simulated Demand for Electronic Cigarettes in First-Time Users:

#### Effects of Nicotine Level

##### 6.1. Preface

The previous chapter was the first to apply simulated demand procedures to an alternative tobacco product: VLNC cigarettes. Despite reduced reinforcing effects, more negative ratings and lower demand ratings than regular cigarettes, VLNC cigarettes were partially substitutable for regular cigarettes, suggesting they could play a role as part of tobacco control policy by reducing nicotine dependence and improving health and financial outcomes for smokers.

This chapter investigates subjective effects and simulated demand for another alternative product that could play a role in tobacco control: e-cigarettes. E-cigarettes could provide a safer source of nicotine for smokers to use instead of more harmful tobacco cigarettes, allowing smokers to choose to attain the reinforcing effects of nicotine by other means. In New Zealand, the Ministry of Health has recommended changes to legislation that would mean nicotine-containing e-cigarettes are regulated as a consumer product (Ministry of Health, 2017). It is therefore important to consider how new users experience e-cigarettes and whether their first-time experience impacts their decision to progress from trial to experimental or ongoing e-cigarette use. This chapter investigates the effect of nicotine on subjective effects ratings and simulated demand for e-cigarettes for first-time e-cigarette users, and whether simulated demand can be predicted using subjective effects ratings.

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Supplementary material is provided at the end of the chapter.

## 6.2. Abstract

We explored how subjective effects and simulated demand for e-cigarettes varied with nicotine level for first-time e-cigarette users.

Forty-six adult smokers sampled 0, 6, 12 and 18mg e-cigarettes (“Vype ePen”) *ad-lib* for 5 minutes in a randomised, blinded order, followed by one-hour rest periods. Subjective effects measures (modified Cigarette Evaluation Questionnaire and adverse effects visual analogue scales) and simulated demand tasks (Cigarette Purchase Task and Cross Price Task) were completed following each sampling period.

Nicotine trends were monotonic for subjective effects; as nicotine increased, reward, craving reduction and aversion increased, while taste/enjoyment properties decreased. However nicotine trends were non-monotonic for several demand measures: Essential value and maximum amount of money spent per day were highest for 6mg and lowest for 12mg, with 0 and 18mg falling in between. Demand for e-cigarettes was best predicted by ratings of psychological reward and satisfaction. Cross price elasticity estimates were significantly positive and unrelated to nicotine, indicating that both nicotine and non-nicotine e-cigarettes were partially substitutable for regular cigarettes.

Results show that the relationship between nicotine level and simulated demand for e-cigarettes is complex: As nicotine increased, alleviation of withdrawal symptoms increased but taste and enjoyment qualities decreased. These factors predict simulated demand for e-cigarettes. If these results correspond with actual behaviour, switching to e-cigarettes could lower smokers’ nicotine intake and thus dependence, which may reduce their chances of relapse to smoking.

### 6.3. Introduction

By providing nicotine replacement while also addressing the psychological factors and behavioural cues that act as barriers to smoking cessation, electronic cigarettes (e-cigarettes) may function as a substitute for regular cigarettes (Farsalinos & Le Houezec, 2015; Glynn, 2014; Hajek, 2014). It is therefore important to understand how smokers experience e-cigarettes relative to regular cigarettes in terms of subjective ratings, reducing nicotine withdrawal symptoms, adverse effects and demand. Experimental and survey studies demonstrate that e-cigarettes can alleviate withdrawal symptoms (Adriaens et al., 2014; Bullen et al., 2010; D'Ruiz et al., 2015; Dawkins & Corcoran, 2014; Dawkins, Turner, & Crowe, 2013; Dawkins et al., 2012; Dawkins, Turner, Roberts, et al., 2013; Eissenberg, 2010; Etter & Bullen, 2011; McPherson et al., 2016; Vansickel et al., 2010; Vansickel & Eissenberg, 2013; Wagener et al., 2014). Although they are rated as less favourable than own-brand cigarettes (Grace et al., 2015b; McPherson et al., 2016; Vansickel et al., 2010; Wagener et al., 2014; Walele et al., 2016b), e-cigarettes are rated as equally or more appealing and favourable relative to other nicotine replacement products (Bullen et al., 2010; Steinberg et al., 2014).

As the reinforcing component of tobacco, the level of nicotine available in e-cigarettes may have an impact on subjective effects but the research is limited. While 0mg e-cigarettes can reduce withdrawal symptoms (Bullen et al., 2010; Dawkins, Turner, & Crowe, 2013; Dawkins et al., 2012), studies have found significantly greater reductions in desire to smoke and withdrawal symptoms after using 16-18mg e-cigarettes than using 0mg e-cigarettes (Bullen et al., 2010; Dawkins, Turner, & Crowe, 2013; Dawkins et al., 2012), suggesting that nicotine is an important factor in alleviating nicotine withdrawal symptoms. One study found that nicotine level in e-cigarettes was not related to reductions in withdrawal

symptoms or craving (Walele et al., 2016a). However nicotine blood concentrations were low so poor nicotine delivery may explain the results.

Other studies compared the subjective effects for combustible cigarettes and other nicotine delivery devices of different nicotine contents. Lower quality, satisfaction, psychological reward, enjoyment of sensations and craving reduction ratings were found for low nicotine content cigarettes (0.4mg/g and 1mg/g) than intermediate or higher nicotine content cigarettes (2mg/g or higher) (Benowitz et al., 2006; Hatsukami, Heishman, et al., 2013). Rose, Turner, Murugesan, Behm, and Laugesen (2010) compared the subjective effects of a prototype aerosol delivery system which is different to an e-cigarette but delivers 0, 10, 20 or 30mg of nicotine pyruvate (NP) per 35ml puff. Nicotine-containing inhalations were significantly more satisfying than the placebo. Although the trend was not tested, results suggested that satisfaction was greatest for the 20mg inhalation and adverse effects increased as nicotine content increased. These studies suggest that the level of nicotine in the e-liquid may play a role in determining the subjective effects of e-cigarette use.

Economic factors, such as increasing tobacco excise taxes, might also encourage smokers to purchase e-cigarettes and use them instead of regular cigarettes. Cross-price elasticity (CPE) is a measure of the relative change in demand for an alternative commodity available at a constant price given a change in price of an original commodity, calculating the slope of the relationship between consumption of the alternative and price of the original in log-log units (Bickel, Degrandpre, & Higgins, 1995). Behavioural economic studies using simulated demand questionnaires and virtual online marketplaces have found that CPE estimates for e-cigarettes are significantly positive, indicating that e-cigarettes are at least partially substitutable for regular cigarettes (Grace et al., 2015b; Quisenberry et al., 2016). However to our knowledge there are no studies which have examined whether demand or CPE for e-cigarettes depends on the nicotine content of the cartridges or e-liquid.

E-cigarettes have the potential to enhance tobacco control efforts by acting as a substitute for regular cigarettes by reducing craving and withdrawal symptoms, and thus demand for regular cigarettes. Rees et al. (2009) hypothesise that product perceptions and response determine the likelihood of initial and subsequent use of alternative products. Based on this idea, we were specifically interested in inexperienced users' first impressions, and how these affected hypothetical purchasing. Given the addictive nature of nicotine, it is important to consider how subjective effects and demand are affected by the nicotine content of the e-cigarette e-liquid or cartridge. We planned to identify how subjective effects and simulated demand by for second-generation e-cigarettes vary with nicotine content for inexperienced users, and whether subjective effects predict simulated demand after smokers' first experience using e-cigarettes. Based on previous research comparing the subjective effects of nicotine in other products (Donny et al., 2015; Rose et al., 2010) we predicted that some positive nicotine content levels would be favoured over the 0mg cartridge, though based on the existing evidence it is unclear what the trend with nicotine would be. We also wanted to explore if trends in nicotine demand corresponded with trends in subjective effects, and whether demand could be predicted based on subjective effects.

## **6.4. Method**

**6.4.1. Participants.** 46 adult smokers were recruited by community and internet advertisement in Christchurch and Wellington. They were required to be adult, daily smokers of tobacco cigarettes and the following exclusion criteria were applied: previous or current use of e-cigarettes, current use of nicotine replacement products or other smoking cessation medication, pregnant or breastfeeding, and suffering from any acute or chronic respiratory, cardiovascular, hepatic or renal disease.

**6.4.2. Procedure.** Participants provided written informed consent, completed online questionnaires and attended two laboratory sessions. Participants were required to be

smokefree for 12 hours prior to each session which was verified by measuring alveolar carbon monoxide (CO) with a Smokerlyzer CO monitor. Alveolar CO levels of up to and including 10ppm were interpreted as supporting 12 hour abstinence (Breland et al., 2016). Over the two sessions they sampled a Vype ePen with four cartridges (25-50% glycerol; 10- <25% propane-1,2-diol; Golden Tobacco flavour) with varying nicotine content (0, 6, 12 and 18mg/ml) in a randomised order. This range of nicotine levels was chosen as representative of the range commonly available for purchase. Participants were blinded to the nicotine content and order of the cartridges but investigators were not. The protocol for both sessions was as follows. After baseline assessment of nicotine withdrawal symptoms, participants were instructed to use the e-cigarette (with one of the four cartridges) *ad libitum* for a 5-minute period. After the sampling period, participants completed questionnaires and simulated demand tasks followed by a 60-minute rest period during which they did not smoke or use the e-cigarette. At the end of the 60-minute rest period the process was repeated with a different e-cigarette cartridge. The study was approved by the Northern-B Health and Disability Ethics (HDEC) Committee (15/NTB/56).

### **6.4.3. Measures**

**6.4.3.1. Online questionnaires.** These included demographic information, ethnicity categorisation, smoking history, dependence measures and a simulated demand task for own-brand cigarettes. Dependence measures included the Fagerström Test of Nicotine Dependence (FTND) (Heatherton et al., 1991) and the Glover-Nilsson Smoking Behaviour Questionnaire (GNSBQ) (Glover et al., 2005). The GNSBQ assesses the cognitive, social and behavioural effects of tobacco dependence; it has good internal consistency and test-retest reliability, and is significantly correlated with nicotine craving (Rath et al., 2013).

The Cigarette Purchase Task (CPT) was used to assess simulated demand for participants' own-brand cigarettes (MacKillop et al., 2008). Additional information about the CPT is included in the supplementary material.

**6.4.3.2. Session measures.** During the session, participants completed questionnaires about subjective effects and simulated demand for e-cigarettes. These included the modified Cigarette Evaluation Questionnaire (mCEQ) (Rose et al., 2000) and 8 VAS items about the common adverse effects of nicotine replacement products rated from 1 (not at all) to 10 (extremely). The mCEQ assesses the reinforcing effects of smoking on four subscales including satisfaction, psychological reward, aversion and craving reduction (Rose et al., 2000). It has good test-retest reliability and the validity of the multidimensional framework is supported (Cappelleri et al., 2007). The 8 VAS items about adverse effects included throat/mouth irritation, aching jaw, nausea, flatulence/belching/hiccups/heartburn, vertigo/feeling high, headache, sweatiness/clammy skin, and heart palpitations (Bullen et al., 2010; Dawkins, Turner, Roberts, et al., 2013; Steinberg et al., 2014; Vansickel et al., 2010; Vansickel & Eissenberg, 2013).

Participants also completed an adapted CPT (MacKillop et al., 2008) to assess simulated demand for e-cigarettes, and a cross-price task to assess cross-price elasticity for e-cigarettes. The cross price task examined demand for regular cigarettes and e-cigarettes at three increasing prices of regular cigarettes while the price of e-cigarettes remained constant and lower. Information about the adaptation of the CPT and the cross-price task are included in the Supplementary Material.

#### **6.4.4. Data Analysis**

Repeated-measures analysis of variance (ANOVA) with polynomial contrasts was used to compare trends for subjective effects and demand for the four cartridges. Initially repeated-measures ANOVA were run with nicotine as a within-groups factor and gender and



cigarette type usually smoked (factory-made or RYO) as a between-groups factor. Gender and cigarette type usually smoked were subsequently omitted from analyses as there were no main effects or interactions.

Analyses were run to test for potential order effects but there were no significant effects of overall order of the four cartridges, session order or within session order on subjective effects or simulated demand measures [ $p>.05$ ]. Stein et al's (2015) algorithm was used to identify non-systematic data for the CPT and for other measures individual data points that were more than 3 standard deviations from the mean were identified as outliers and removed from the analysis.

## 6.5. Results

### 6.5.1. Participant characteristics. Participant characteristics are shown in Table 5.

The average FTND score was 3.20 ( $SD=2.25$ ) and was significantly higher for smokers of RYO cigarettes than smokers of factory-made (FM) cigarettes [ $M_s=4.10$  and  $2.42$  respectively;  $t(43)=-2.661, p<.05, d=.79$ ], with no differences by gender [ $t(43)=-.385, p=.702$ ] or ethnicity [ $F(2,42)=1.217, p=.306$ ]. . The average GNSBQ score was 16.96 ( $SD=5.50$ ) with no differences by gender [ $t(43)=-1.204, p=.235$ ], ethnicity [ $F(2,42)=2.192, p=.124$ ] or cigarette type usually smoked [ $t(43)=-1.311, p=.197$ ]. The average number of cigarettes smoked per day (cigs/day) was 10.32 ( $SD=6.69$ ) with no significant differences by gender [ $t(42)=-1.126, p=.267$ ], ethnicity [ $F(2,41)=1.979, p=.151$ ] or cigarette type usually smoked [ $t(43)=-1.204, p=.235$ ].

Table 5. Participant characteristics (N=46)

<i>Demographic</i>	<i>M</i>	<i>SD</i>
Age	26.76	10.605
<i>Gender</i>	<i>%</i>	<i>n</i>
Male	73.3	33
Female	26.7	12
<i>Ethnicity</i>	<i>%</i>	<i>N</i>
New Zealand European	71.1	32
Māori	6.7	3
Other	22.2	10
<i>Cigarette type usually smoked</i>	<i>%</i>	<i>n</i>
Factory-Made	53.3	24
Roll-Your-Own	46.7	21
<i>Smoking Information</i>	<i>M</i>	<i>SD</i>
Nicotine Dependence (FTND)	3.20	2.252
Behavioural Dependence (GNSBQ)	16.96	5.498
Years Smoked	9.133	5.498
Cigarettes per day	10.32	6.688

*Note:* FTND = Fagerström Test of Nicotine Dependence, GNSBQ = Glover-Nilsson Smoking Behaviour Questionnaire

**6.5.2. Subjective ratings.** Figure 10 shows that psychological reward, aversion and craving reduction increased as nicotine content increased, whereas satisfaction decreased. Repeated-measures ANOVAs with nicotine (0mg, 6mg, 12mg and 18mg) as a repeated-measures factor confirmed these observations. Main effects of nicotine were found for Psychological Reward [ $F(3,135)=3.936, p<.05, \eta_p^2=.08$ ], Aversion

$[F(3,135)=5.916, p<.001, \eta_p^2=.12]$  and Craving Reduction  $[F(3,135)=5.009, p<.005, \eta_p^2=.10]$ .

Polynomial contrasts found significant linear trends  $[p=.04; p<.001; \text{and } p=.002 \text{ respectively}]$

but no quadratic  $[p=.06; p=.25; p=.43]$  or cubic effects  $[p=.06; p=.29; p=.07]$ . For

Satisfaction, the main effect of nicotine was not significant  $[F(3,135)=2.507, p=.06]$  but

polynomial contrasts showed a significant linear trend of nicotine  $[p=.049]$  whereby

Satisfaction decreased as nicotine increased, but no quadratic  $[p=.95]$  or cubic  $[p=.35]$  trends.

For Satisfaction items, polynomial contrasts were conducted. These showed significant

linear decreasing trends for Enjoyment  $[p=.033]$  and Taste  $[p=.0004]$  with nicotine, but not

for Satisfaction  $[p=0.687]$ .

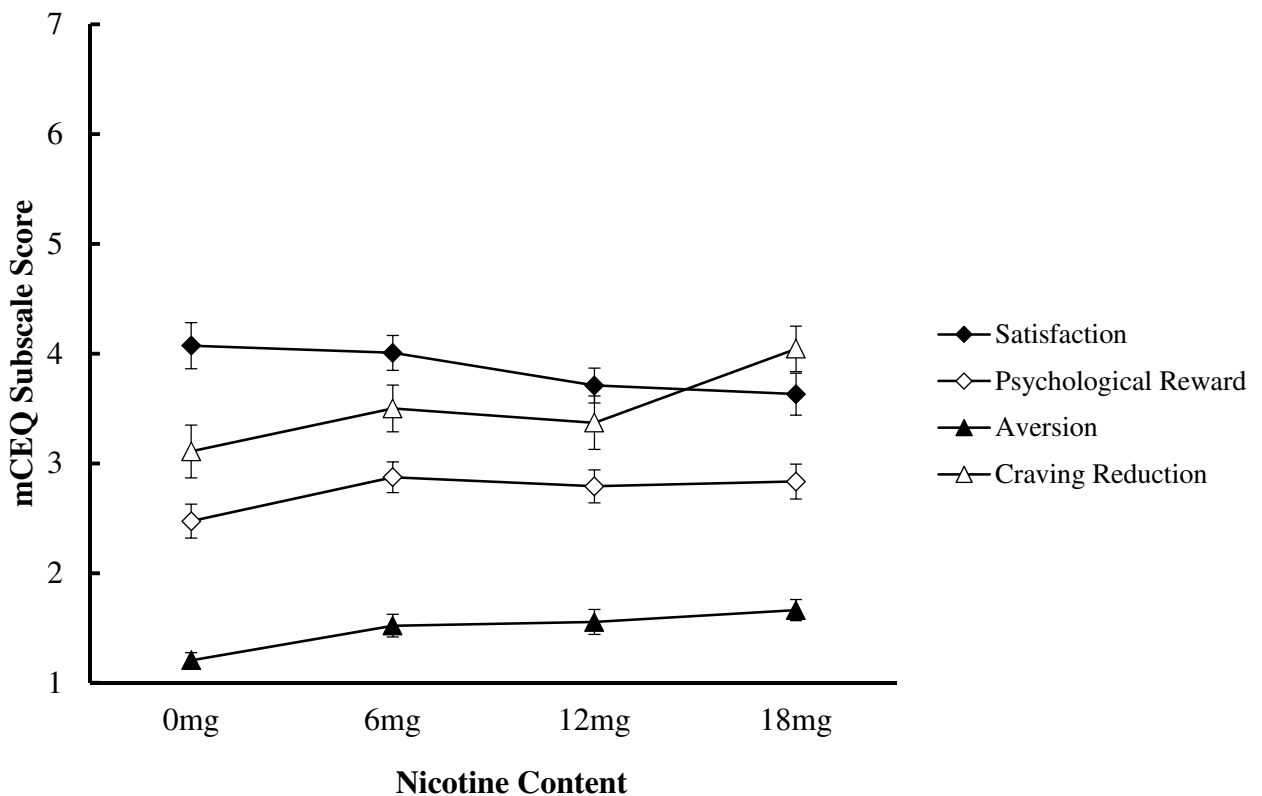


Figure 10. Scores on Modified Cigarette Evaluation Questionnaire (mCEQ) shown separately for four different nicotine content e-liquids (0mg, 6mg, 12mg, 18mg).

Figure 11 shows common adverse effects rated on a 10-point visual analogue scale separately for the four different strength cartridges. Only items with significant main effects and polynomial contrasts are shown: mouth/throat irritation, vertigo and headache. Main effects of nicotine were found for mouth/throat irritation [ $F(3,138)=23.146, p<.001, \eta p^2=.33$ ], vertigo/feeling high [ $F(3,138)=5.572, p<.005, \eta p^2=.11$ ], and headache [ $F(3,138)=3.202, p<.05, \eta p^2=.07$ ]. Repeated-measures ANOVAs showed significant linear effects of nicotine on mouth/throat irritation [ $p<.0001$ ], vertigo/feeling high [ $p=.0013$ ], and headache [ $p=.0114$ ]. No significant quadratic or cubic effects were found.

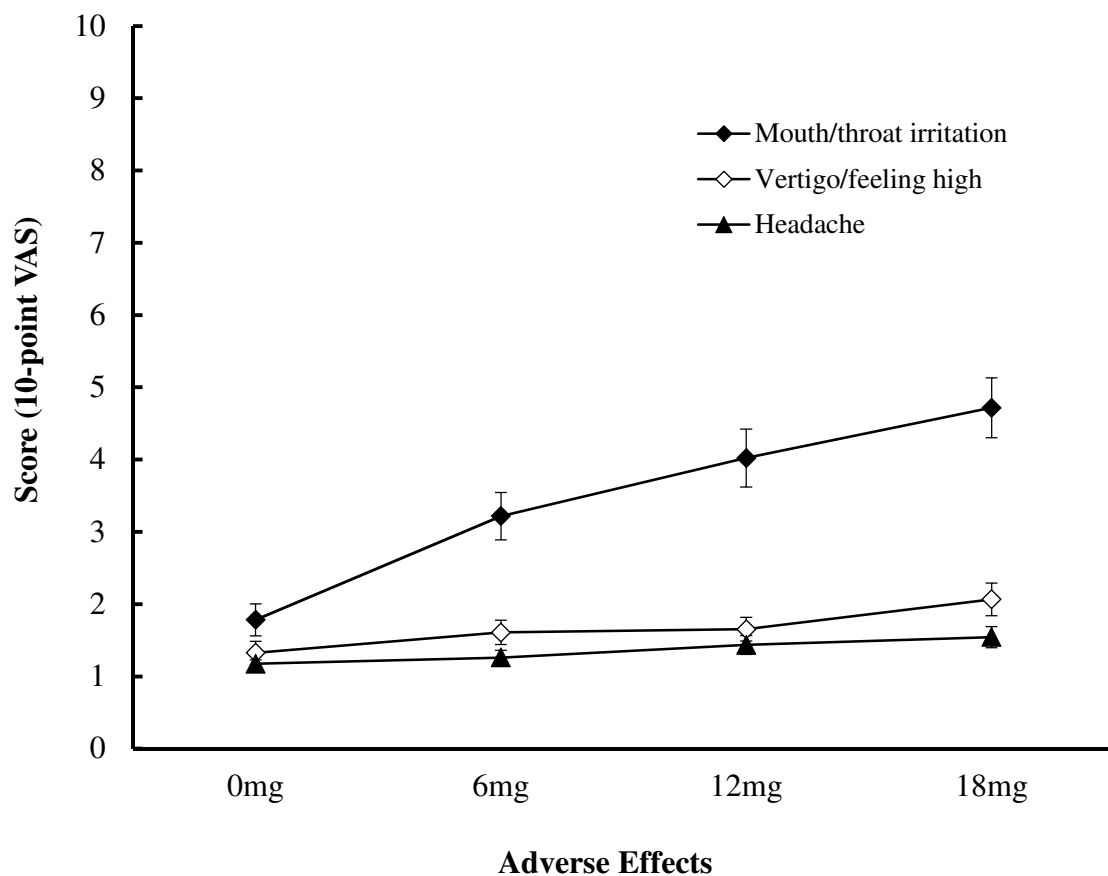


Figure 11. Scores on 10-point VAS for common adverse effects shown separately for four different nicotine content e-liquids (0mg, 6mg, 12mg, 18mg). Error bars indicate  $\pm 1$  SE.

**6.5.3. Demand.** Figure 12 shows average demand for regular cigarettes and e-cigarettes with the four different nicotine content cartridges reported on the CPT. The results were characteristic of demand curves for inelastic commodities with consumption mostly high and decreasing sharply at relatively high prices. The modified exponential model (Koffarnus, Franck, et al., 2015) provided a good description of the average data for regular cigarettes and e-cigarettes with varying nicotine content cartridges, accounting for 94-96% of the variance in the average data. Fits to the individual data were more variable but the model still described results well, accounting for 91-92% of the variance (median values). A repeated-measures ANOVA was conducted on the CPT data for the four nicotine content e-cigarettes. There was a significant main effect of price [ $F(19,798)=118.4881, p<.001, \eta_p^2 = .74$ ] and a significant price x nicotine interaction effect [ $F(57,2394)=1.5717, p<.005, \eta_p^2 = .04$ ]. As Figure 13 shows, demand was a non-monotonic function of nicotine level for prices from NZ\$0.40 to NZ\$2.00 per vape with highest demand for 6mg and lowest for 12mg. Polynomial contrasts confirmed significant cubic effects of nicotine level from prices NZ\$0.40 to NZ\$2.00 per vape [ $p<.05$ ], and Tukey HSD pairwise analyses confirmed greater demand for 6mg than 12mg at NZ\$0.60 and NZ\$0.80 per vape (just under current market price for cigarettes in New Zealand). When regular cigarettes were included in the analysis, repeated-measures ANOVA found significant effect of price [ $F(19,798)=151.0115, p<.001, \eta_p^2 = .78$ ], cigarette type [ $F(4,168)=4.6149, p<.005, \eta_p^2 = .10$ ].

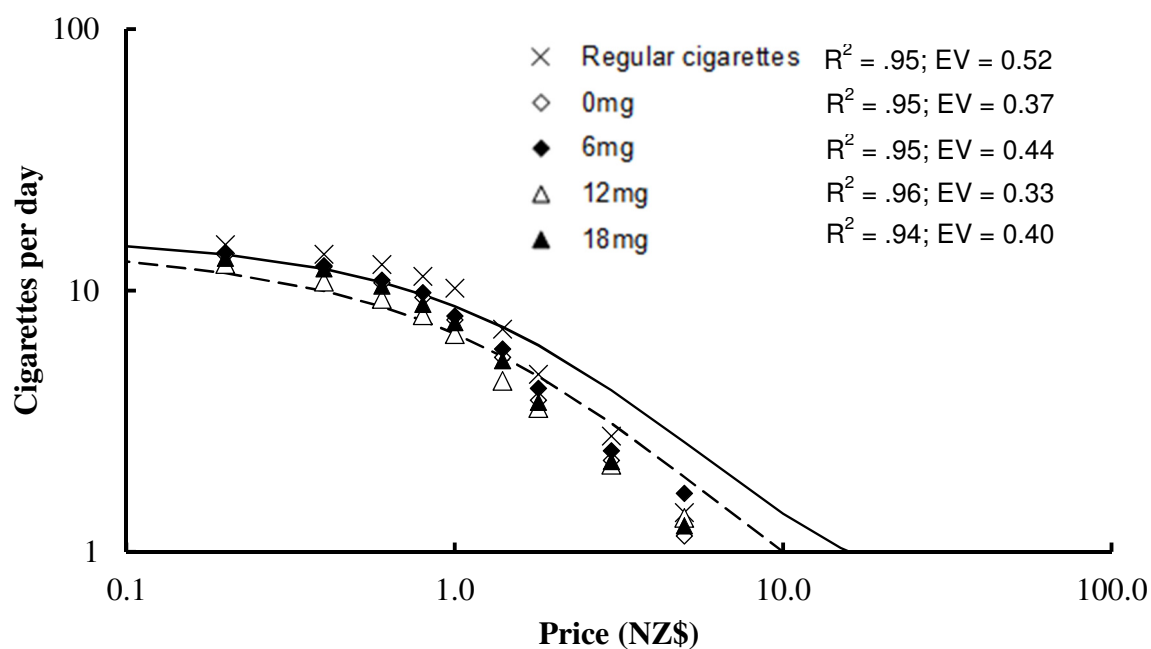


Figure 12. Average simulated demand for regular cigarettes (crosses) and e-cigarettes with varying nicotine content cartridges using the CPT plotted on logarithmic axes. Solid lines indicate fits of the modified exponentiated model to demand for regular cigarettes; dashed lines indicate fits to average e-cigarette demand.

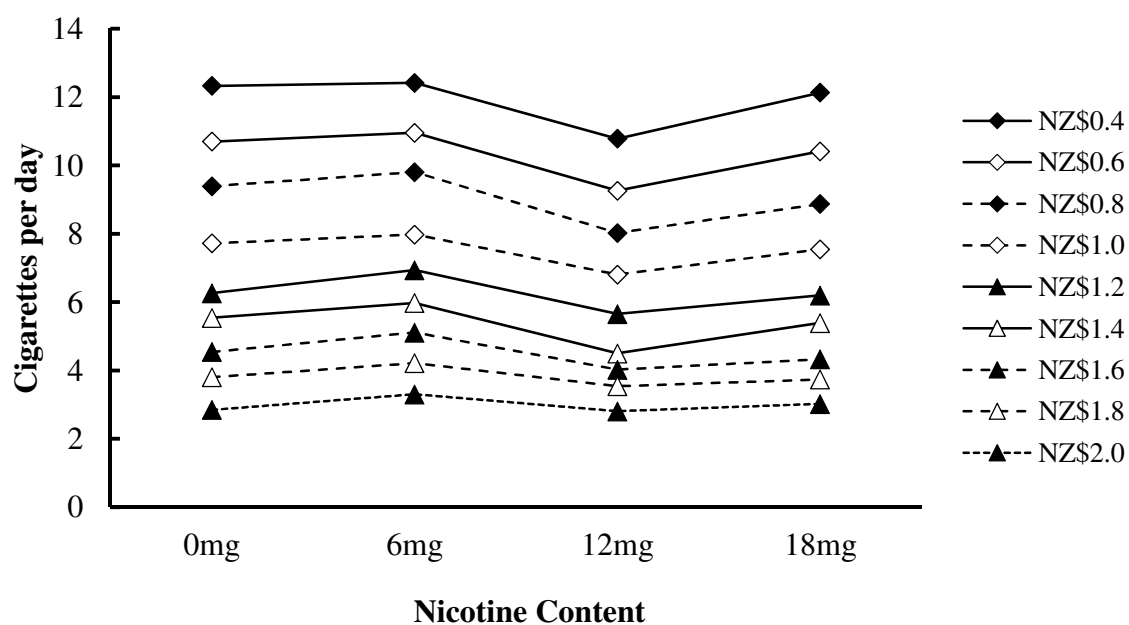


Figure 13. Average vapes per day estimated for 0mg, 6mg, 12mg and 18mg nicotine e-cigarette cartridges at prices from NZ\$0.40 to NZ\$2.00 on the CPT.

Table S2 in the Supplementary Material shows means and correlations for demand metrics derived from the CPT and the modified exponential model (Koffarnus, Franck, et al., 2015) for 0mg, 6mg, 12mg and 18mg e-cigarette cartridges and regular cigarettes. Repeated-measures ANOVAs found significant main effects of nicotine were found for EV [ $F(3,141)=2.707, p<.05, \eta_p^2=.05$ ] and derived  $O_{\max}$  [ $F(3,111)=2.801, p<.05, \eta_p^2=.07$ ] and polynomial contrasts showed significant cubic trends for both measures [ $p=.0001$  for both], shown in the figure in Figure B.2. Pairwise analysis (Tukey HSD) showed that 6mg cartridges had higher EV [ $p=.037$ ] and derived  $O_{\max}$  [ $p=.037$ ] than 12mg cartridges, but not 0mg or 18mg cartridges. When regular cigarettes were included in the analysis, repeated-measures ANOVA found significant main effects of cigarette type on EV [ $F(4,156)=3.166, p<.05, \eta_p^2=.08$ ], derived  $O_{\max}$  [ $F(4,144)=2.866, p<.05, \eta_p^2=.07$ ] and observed  $O_{\max}$  [ $F(4,156)=5.399, p<.001, \eta_p^2=.12$ ]. Pairwise analyses (Tukey HSD) indicated that EV and derived  $O_{\max}$  were higher for regular cigarettes than 0mg [ $p=.015$ ] or 12mg cartridges [ $p=.003$ ], and that observed  $O_{\max}$  was higher for regular cigarettes than all cartridges [ $p=.003, .049, .001$  and  $.002$  respectively].

We conducted an exploratory analysis to model simulated demand measures (EV and derived  $O_{\max}$ ) using the mCEQ subscale scores. We used mixed model analyses with a best-fitting covariance structure (compound symmetry), and identified which combination of mCEQ subscales provided an optimal account of EV and  $O_{\max}$  according to model comparison criteria (lowest BIC). Psychological Reward and Satisfaction were the best predictors of EV [ $b=.080, p<.001$ ;  $b=.042, p=.009$ , respectively] and  $O_{\max}$  [ $b=1.992, p<.001$ ;  $b=1.033, p=.009$ , respectively]. Thus across nicotine levels, participants' demand for e-cigarettes was positively related to Psychological Reward and Satisfaction, with the former having relatively greater weight as a predictor.

CPE estimates were calculated for individual participants as the regression slopes of (log) e-cigarette demand on (log) regular cigarette price. Average CPEs were 0.24 for 0mg [95%CI=0.12,0.35], 0.20 for 6mg [95%CI=0.20,0.30], 0.23 for 12mg [95%CI=0.12,0.37] and 0.25 for 18mg [95%CI=0.14,0.37]. All CPE values were significantly positive [ $p<.05$ ], indicating that e-cigarette cartridges are partially substitutable for regular cigarettes. However, a positive CPE was only found for 41%, 37%, 44% and 44% of the sample for each cartridge respectively. This indicates that, for more than half of participants, demand for e-cigarette cartridges did not increase with increasing price of regular cigarettes. Repeated-measures ANOVA confirmed that CPE estimates were not significantly different for the different strength cartridges [ $F(3,138)=0.296, p=.828$ ] and polynomial contrasts found no significant linear [ $p=.64$ ], quadratic [ $p=.44$ ] or cubic trends [ $p=.72$ ]. Correlation analyses (summarised in Supplementary Table S3) showed that CPE was not correlated with smoking dependence or habit, and was not consistently correlated with subjective effects or demand measures.

## 6.6. Discussion

Significant linear trends indicated that Psychological Reward and Craving Reduction increased as nicotine content increased which is consistent with previous research showing that nicotine-containing cigarettes reduce craving and withdrawal more than placebo e-cigarettes (Bullen et al., 2010; Dawkins, Turner, & Crowe, 2013; Dawkins et al., 2012) and that higher nicotine cigarettes reduce craving and withdrawal more than lower nicotine content cigarettes (Benowitz et al., 2006; Hatsukami, Heishman, et al., 2013). Significant linear trends were also found for Aversion, and for three of the adverse effects: Mouth/throat irritation, vertigo/feeling high and headache. This is consistent with previous studies that find higher adverse effects for higher levels of nicotine pyruvate per puff using an aerosol delivery system (Rose et al., 2010) and higher adverse effects ratings for a 16mg e-cigarette than a



0mg e-cigarette (Bullen et al., 2010). In contrast to the other subscales, Satisfaction ratings significantly decreased as nicotine content increased, perhaps due to the increase in adverse effects noted above. This suggests that enjoyment and taste, the sensory aspects of e-cigarette use, may be independent of withdrawal symptom alleviation and craving reduction, which increase with nicotine.

Similar demand curves were found for all four nicotine content e-cigarette cartridges and regular cigarettes, with patterns of decreasing demand with increasing price. Simulated demand (EV and  $O_{\max}$ , and demand at realistic prices) was greatest for low-nicotine 6mg cartridges, while the 12mg cartridges were lowest in demand. These results suggest that the relationship between nicotine content and demand for e-cigarettes may be more complex than the linear relationships between nicotine content and subjective effects.

Our mixed model analyses suggested that the non-monotonic relationships between nicotine and demand may be a product of different weightings of satisfaction and psychological reward; intent to purchase e-cigarettes depends on a balance of enjoyment and taste qualities and withdrawal symptom alleviation properties. The 6mg cartridges may represent the optimal balance between delivering enough nicotine to be rewarding, but not so high as to be associated with reduced taste and enjoyment. In contrast, 12mg cartridges may contain enough nicotine to be aversive and less enjoyable, whilst not delivering enough nicotine for sufficient reward and craving reduction. While these conclusions are tentative, it is likely to be important to balance the sensory elements of e-cigarettes and their e-liquids with the delivery of nicotine in order for smokers when making the hypothetical decision to purchase them.

Positive CPE estimates were found for all four nicotine content cartridges and their hypothetical availability led to reductions in the simulated demand for regular cigarettes. Comparable CPE estimates indicated that all four cartridges were partially substitutable for

regular cigarettes. However, positive CPE estimates were found for less than half of the sample, indicating that most smokers would not substitute e-cigarettes for their regular cigarettes. Our findings suggest that, after a first exposure to e-cigarettes, some smokers appear to perceive e-cigarettes as partially substitutable for regular cigarettes, support the idea that price differentials or other strategies may be required for more smokers to make the decision to switch to e-cigarettes. It is also important to note that CPE was not consistently correlated with any subjective effects ratings or other demand measures, indicating that the decision to use e-cigarettes may be more complex than whether they are enjoyable to use, reduce craving and withdrawal symptoms, or are valued similarly to cigarettes.

To our knowledge this is the first study to describe and quantify nicotine trends on subjective effects and demand for first-time e-cigarette users. It confirms that after their first experience using e-cigarettes, smokers' self-reported hypothetical purchasing behaviour indicated that e-cigarettes were partially substitutable for regular cigarettes regardless of nicotine content. In addition, the findings specifically highlight that nicotine level, withdrawal symptom alleviation and taste and enjoyment factors could affect demand for and potentially future uptake of e-cigarettes after first-time use.

It is important to note that because we studied first-time e-cigarette users, our results do not necessarily generalize to more experienced or longer-term users. Existing evidence shows different vaping topography and relatively poor nicotine delivery in inexperienced users (Farsalinos, Romagna, Tsiapras, Kyrzopoulos, & Voudris, 2013c; Farsalinos, Spyrou, et al., 2014) compared to experienced users, and so how subjective effects depend on nicotine level may differ for experienced users. Nonetheless, the sampling period in this study reflects the participants' first-time experience regardless of the level of nicotine delivery and vaping topography; an important part of the trialling process which may determine ongoing e-cigarette use (Rees et al., 2009). It is also important to acknowledge that the participants were

predominantly young and male, with relatively low nicotine dependence, and so these results may not apply to broader populations of first-time users with higher levels of dependence.

It is also important to highlight that our findings regarding the effects of nicotine on subjective effects and demand must be considered tentative due to the lack of pharmacokinetic plasma nicotine assessment and the uncontrolled self-administration period. Although we cannot confirm if residual effects of nicotine remained following the rest period before participants sampled the next cartridge, we used a one hour rest period consistent with previous studies (Dawkins & Corcoran, 2014; Eissenberg, 2010; Vansickel et al., 2010), which have shown that plasma nicotine decreased to a level not significantly different to baseline after a one hour rest period (Eissenberg, 2010; Vansickel et al., 2010). The lack of order effects found in our study also supports the idea that there were no carryover effects of previous cartridge sampled. Second, the uncontrolled self-administration period limits interpretation of the trends reported in this study in which the highest demand was for the lower nicotine (6mg) cartridges. Participants may have used the more enjoyable 6mg cartridges more intensively than the more aversive higher nicotine content cartridges, which may have led to higher nicotine exposure than would be assumed based on the cartridge labelling. As e-cigarette topography and plasma nicotine were not assessed, we cannot conclude whether the higher demand for 6mg cartridges was due to the properties of the cartridge or the intensity of use during the sampling period. However, it is important to note that variation in vaping topography cannot explain the relationship between subjective effects and simulated demand that we observed.

Overall, we found that the ability of the e-cigarette to alleviate craving and withdrawal symptoms increased as nicotine content increased, however adverse effects also increased with nicotine content, while enjoyment and taste decreased. It appears that inexperienced participants consider two factors in the decision to use e-cigarettes: 1)

psychological reward and 2) satisfaction. As such, there may be more demand for lower nicotine cartridges (6mg) rather than those of higher nicotine content as may have been expected due to the consideration of both the rewarding properties of nicotine in alleviating withdrawal symptoms, and taste and enjoyment during vaping. One implication of this may be that, if smokers who choose to switch to e-cigarettes do indeed opt for lower nicotine e-liquid or cartridges, in the process they may reduce their nicotine intake and dependence, which may reduce their chances of relapse. It would be useful for additional research to focus on demand for different nicotine content e-cigarettes for more experienced users, and on longer-term patterns of use of e-cigarettes of differing nicotine contents.

## 6.7. Supplementary Material 1. Simulated Demand Measures

**6.7.1. Cigarette Purchase Task.** The CPT asks participants to estimate their cigarette consumption on a typical day at escalating prices with their existing resources, no access to any other sources of tobacco and no stockpiling. The price range used was broad, to maximise the chances of attaining a breakpoint, including 20 prices from NZ\$0 to NZ\$25 per cigarette (USD\$1 = NZ\$1.40). The prices consisted of: NZ\$0.2 increases from NZ\$0 to NZ\$2, NZ\$1 increases from NZ\$2 to NZ\$5, NZ\$2.50 increases from NZ\$5 to NZ\$20 and a NZ\$5 increase from NZ\$20 to NZ\$25. Factory-made (FM) cigarette smokers were asked to estimate based on price per cigarette and administered the same price schedule as above, whereas roll-your-own (RYO) cigarette smokers were asked to estimate based on price per 30g pouch. Current market price was in the same position on both scales [approximately NZ\$0.80 per FM and NZ\$40 per 30g tobacco package for RYO] and changes in price relative to current market price were constant across both versions of the questionnaire.

**6.7.2. Adapted E-Cigarette Purchase Task.** Participants were asked to estimate how many 1-5 minute ‘vapes’ of the e-cigarette they would have per day at escalating prices per vape with their existing resources, no access to other forms of tobacco and no stockpiling. The price range used was the same as the CPT for their own-brand cigarettes, from NZ\$0 to NZ\$25.

**6.7.3. Cigarette Purchase Task analyses.** Several analyses were used to characterise CPT demand curves. Measures were obtained directly from CPT responses and derived from fits of Koffarnus, Franck, Stein and Bickel’s (2015) exponentiated version of Hursh and Silberberg’s (2008) demand model using Microsoft Excel Solver. The equation for the exponentiated model is:

$$Q = Q_0 * 10^{k(e^{-\alpha Q_0 C} - 1)}$$

where  $Q$  is the demand at price  $C$ ,  $Q_0$  is maximum consumption (i.e. demand when cigarettes are free),  $k$  is a constant representing the span of the data in log10 units and  $\alpha$  is elasticity, a fitted parameter which determines how quickly demand falls with increases in price (higher values of  $\alpha$  indicate that demand falls more rapidly with price). Here, we determined  $k$  by subtracting the log10-transformed average consumption at the highest price from log10-transformed average consumption at the lowest price ( $k=1.78$ ). Essential Value (EV) is a definition of value based on sensitivity to price and is inversely proportional to  $\alpha$  (Hursh & Roma, 2016). The formula for EV is:

$$EV = 1/(100 * \alpha * k^{1.5})$$

EV is linearly related to normalised  $P_{\max}$ , the price at which consumption is maximum.  $P_{\max}$  can be obtained from the observed data or calculated using the following formula (Hursh & Roma, 2016):

$$P_{\max} = m/(Q_0 * \alpha * k^{1.5}) \text{ where}$$

$$m = 0.084k + 0.65$$

$O_{\max}$  is the level of response output at  $P_{\max}$ , that is the maximum amount of money spent per day.  $O_{\max}$  can be derived from normalised  $P_{\max}$  or obtained from the observed data.

**6.7.4. Cross-Price Task.** Participants also completed a cross-price task in which they were asked to estimate how many of their own-brand cigarettes they would smoke and how many 1-5 minute vapes of the e-cigarette they would have per day at three escalating prices of their own-brand cigarettes while the price of the e-cigarette vape remained constant. The prices for own-brand cigarettes were intended to represent approximately 0.5x, 1x and 2x the current market price of cigarettes in New Zealand (NZ\$0.40, NZ\$0.80 and NZ\$1.60) while the price of an e-cigarette vape was constant and subsidised (NZ\$0.25).

**6.8. Supplementary Material 2.** Table S2. Mean scores and correlation coefficients for measures of demand derived directly from the CPT and from fits of Koffarnus et al.'s (2015) exponentiated model shown separately for 0mg, 6mg, 12mg and 18mg e-cigarette cartridges and regular cigarettes.

	M (SD)						
	0mg	1.	2.	3.	4.	5.	6.
1. Essential Value	0.57 (1.33)	-					
2. $Q_0$	15.78 (9.61)	0.49*	-				
3. Observed $O_{max}$	16.93 (30.65)	0.84*	0.43*	-			
4. Derived $O_{max}$	14.11 (32.97)	1.00*	0.49*	0.85*	-		
5. $P_{max}$	2.80 (5.82)	0.64*	-0.11	0.54*	0.64*	-	
6. Breakpoint	4.67 (4.32)	0.59*	0.17	0.62*	0.59*	0.61*	-
7. CPE	0.24 (0.38)	-0.11	-0.19	-0.16	-0.11	-0.12	-0.06
	6mg	1.	2.	3.	4.	5.	6.
1. Essential Value	0.60 (1.14)	-					
2. $Q_0$	14.96 (6.42)	0.29	-				
3. Observed $O_{max}$	17.71 (30.04)	0.74*	0.36*	-			
4. Derived $O_{max}$	14.93 (28.37)	1.00*	0.29	0.74*	-		

5. $P_{\max}$	3.34 (4.85)	0.76*	-0.34*	0.45*	-0.76*	-	
6. Breakpoint	5.83 (4.82)	0.75*	-0.06	0.54*	-0.75*	-0.75*	-
7. CPE	0.20 (0.33)	-0.21	0.10	-0.22	-0.21	-0.26	-0.11
	12mg	1.	2.	3.	4.	5.	6.
1. Essential Value	0.59 (1.28)	-					
2. $Q_0$	13.89 (7.74)	0.37*	-				
3. Observed $O_{\max}$	19.55 (44.31)	0.96*	0.44*	-			
4. Derived $O_{\max}$	14.62 (31.90)	1.00*	0.38*	0.96*	-		
5. $P_{\max}$	3.31 (5.72)	0.67*	-0.31*	0.60*	0.67*	-	
6. Breakpoint	4.55 (3.58)	0.55*	0.10	0.55*	0.55*	0.51*	-
7. CPE	0.23 (0.37)	-0.14	-0.20	-0.10	-0.14	0.02	0.15
	18mg	1.	2.	3.	4.	5.	6.
1. Essential Value	0.54 (1.03)	-					
2. $Q_0$	14.07 (7.49)	0.49*	-				
3. Observed $O_{\max}$	17.40 (34.69)	0.76*	0.48*	-			
4. Derived $O_{\max}$	13.47 (25.70)	1.00*	0.49*	0.76*	-		
5. $P_{\max}$	3.00 (4.26)	0.67*	-0.19	0.41*	0.67*	-	
6. Breakpoint	4.84 (4.14)	0.69*	0.03	0.54*	0.69*	0.75*	-



7. CPE	0.25 (0.39)	-0.09	0.07	-0.24	-0.09	-0.17	-0.15
	Regular cigarettes	1.	2.	3.	4.	5.	6.
1. Essential Value	0.52 (0.43)	-					
2. $Q_0$	15.71 (8.47)	0.48*	-				
3. Observed $O_{\max}$	17.61 (17.80)	0.94*	0.48*	-			
4. Derived $O_{\max}$	12.98 (10.54)	0.99*	0.48*	0.95*	-		
5. $P_{\max}$	3.13 (3.16)	0.66*	-0.17	0.53*	0.67*	-	
6. Breakpoint	4.92 (3.49)	0.48*	-0.16	0.40*	0.49*	0.67*	-

Note: SD are listed in parentheses. Asterisks after VLNC cigarette demand scores indicate significant differences from own brand cigarette scores. Asterisks after correlation coefficients indicate significant relationships \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .005$ .

**6.9. Supplementary Material 3.** Table S3. Correlations for Essential Value and Cross-Price Elasticity with smoking habit (cigarettes smoked per day) and dependence (Fagerström Test of Nicotine Dependence, FTND; Glover-Nilsson Smoking Behaviour Questionnaire, GNSBQ), and subjective effects (mCEQ subscales) for 0mg ,6mg, 12mg and 18mg e-cigarette cartridges.

Essential Value					Cross-Price Elasticity			
Smoking Habit and Dependence								
Cigarettes/day	.58*	.56*	.55*	.55*	-.25	-.07	-.24	-.09
FTND	.48*	.46*	.50*	.44*	-.21	-.21	-.32*	-.14
GNSBQ	.19	.16	.18	.12	-.29	-.09	-.03	-.13
0mg Cartridge Rating								
Satisfaction	.08	.13	.05	.00	-.26	-.30	.06	-.26
Psychological Reward	.41*	.44*	.39*	.39*	-.10	-.43*	-.06	-.35*
Aversion	.49*	.49*	.43*	.49*	.05	-.17	-.00	-.12
Craving Reduction	.19	.18	.13	.07	-.19	-.29	.11	-.36*
6mg Cartridge Ratings								
Satisfaction	.14	.16	.13	.18	-.04	-.11	.09	-.17
Psychological Reward	.15	.19	.15	.16	.14	-.03	.23	.06

Aversion	.15	.14	.09	.10	.11	-.05	.23	.06
Craving Reduction	.04	.05	.03	.04	-.03	.05	.31*	-.03
12mg Cartridge Ratings								
Satisfaction	.04	.06	.07	.09	-.12	-.16	.03	-.19
Psychological Reward	.24	.27	.26	.26	-.10	-.07	.16	-.11
Aversion	.05	.07	.04	.03	-.04	-.11	-.08	-.09
Craving Reduction	.22	.26	.23	.21	-.16	-.19	-.08	-.19
18mg Cartridge Ratings								
Satisfaction	.11	.12	.11	.22	.05	-.01	-.05	-.11
Psychological Reward	.26	.30	.29	.35*	.02	-.05	-.08	-.09
Aversion	.01	.02	-.04	.04	.03	.05	.07	.01
Craving Reduction	.06	.08	.09	.08	-.15	.00	.11	-.17

*Note.* Asterisks after correlation coefficients indicate significant relationships \* $p < .05$

## CHAPTER 7

### Predicting Short-Term Uptake of Electronic Cigarettes: Effects of Nicotine, Subjective Effects and Simulated Demand

#### 7.1. Preface

The previous chapter examined subjective effects of and demand for e-cigarettes of different nicotine levels after brief, first-time exposure. For first-time users, withdrawal symptoms alleviation increased as nicotine level increased, however adverse effects increased and enjoyment and taste decreased. A combination of withdrawal symptom alleviation (Psychological Reward) and taste and enjoyment factors (Satisfaction) predicted simulated demand for e-cigarettes, and as such simulated demand was greatest for relatively low nicotine level e-cigarettes (6mg, relative to 0, 12 or 18mg). While the previous study was one of the first to examine trends in subjective effects and demand by nicotine level and to model demand using subjective effects, the use of a single, brief exposure period does not capture how subjective experience may change over time, especially for first-time users.

To our knowledge the study described in the current chapter is the first to examine the subjective effects and patterns of use of e-cigarettes with different nicotine contents for new users with more than a brief, single exposure. This study also tests whether the subjective effects identified as predictive of simulated demand after first-time use in the previous chapter (Psychological Reward and Satisfaction) can be used to predict short-term actual e-cigarette use. This may highlight which product characteristics produce the optimal subjective effects that would encourage uptake of e-cigarettes after trialling them.

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This manuscript has been submitted to Nicotine & Tobacco Research.

Tucker, M.R, Bullen, C., Laugesen, M. & Grace, R. C. (2017) An Investigation into the Effect of Varying Nicotine Content on Electronic Cigarette Subjective Ratings and Demand over a Two Week Period. *Manuscript submitted for publication.*

## 7.2. Abstract

Previous studies have examined subjective effects of e-cigarettes based on a single, brief exposure which may not be related to longer-term effects or behaviour. This study aims to explore the subjective effects of e-cigarettes and patterns of smoking and e-cigarette use over 2-week periods, and to predict e-cigarette use using subjective effects ratings.

Adult daily smokers ( $N = 35$ ) were provided four e-cigarette cartridges (0, 6, 12 and 18mg nicotine) in a randomised, blinded order over four 2-week periods. All had previously been exposed for the first time to e-cigarettes in a laboratory session. Daily cigarette smoking and e-cigarette use was monitored using ecological momentary analysis and participants completed the modified Cigarette Evaluation Questionnaire after each 2-week period.

Participants smoked fewer cigarettes per day when e-cigarettes were available relative to baseline. Fewer cigarettes were smoked when participants used e-cigarettes with nicotine. Use of nicotine-containing cartridges was associated with greater craving reduction than non-nicotine cartridges. Two subjective effects, Psychological Reward and Satisfaction, that in a laboratory study with the same participants had predicted simulated demand, predicted e-cigarette use behaviour over a 2-week period.

Response to trialling e-cigarettes is an important factor in determining subsequent experimental and possibly longer-term use.

### 7.3. Introduction

Electronic cigarettes (e-cigarettes) may have a dual role for smokers: delivering nicotine to address the biological aspect of nicotine dependence; and simulating comparable motor actions and sensory experiences to address the behavioural aspect of cigarette smoking (Buchhalter et al., 2005). These properties may allow smokers to quit smoking or reduce their cigarette use (McRobbie et al., 2014). It is therefore important to understand smokers' subjective experience of e-cigarettes, whether their preferences are maintained over time, and how these preferences affect patterns of cigarette use.

Experimental and survey studies show that e-cigarettes can alleviate nicotine withdrawal symptoms (Adriaens et al., 2014; Bullen et al., 2010; D'Ruiz et al., 2015; Dawkins & Corcoran, 2014; Dawkins, Turner, & Crowe, 2013; Dawkins et al., 2012; Dawkins, Turner, Roberts, et al., 2013; Eissenberg, 2010; Etter & Bullen, 2011; McPherson et al., 2016; Vansickel et al., 2010; Vansickel & Eissenberg, 2013; Wagener et al., 2014). These studies suggest that although e-cigarettes are rated as less favourable than regular cigarettes (Grace et al., 2015b; McPherson et al., 2016; Vansickel et al., 2010; Wagener et al., 2014; Walele et al., 2016b), they are equally or more appealing and favourable than other nicotine replacement products (Bullen et al., 2010; Steinberg et al., 2014).

The role of nicotine is also considered to be important in smokers' subjective experience of e-cigarette use, though the relationship between nicotine content and subjective experience is unclear. While e-cigarettes with no nicotine can reduce withdrawal symptoms (Bullen et al., 2010; Dawkins, Turner, & Crowe, 2013; Dawkins et al., 2012), studies have found significantly greater reductions in desire to smoke and withdrawal symptoms after using 16-18mg e-cigarettes than 0mg e-cigarettes (Bullen et al., 2010; Dawkins, Turner, & Crowe, 2013; Dawkins et al., 2012), suggesting that nicotine is an important factor in alleviating nicotine withdrawal symptoms. Conversely, one study comparing e-cigarette

nicotine levels (0, 4, 9 and 20mg) found that nicotine level was not related to reductions in withdrawal symptoms or craving (Walele et al., 2016a). However the authors noted that all four nicotine content e-cigarettes failed to reach high blood concentration, so poor nicotine delivery may explain the results. By contrast, in a previous study we found that for first-time e-cigarette users, craving and withdrawal symptom reduction increased as nicotine increased while satisfaction (primarily taste and enjoyment factors) decreased (Tucker, Bullen, et al., 2017a). Thus the relationship between subjective effects and nicotine content is unclear.

One limitation of prior research on the subjective effects of e-cigarettes is the use of single, short-duration sessions prior to rating subjective effects (Evans & Hoffman, 2014). Participants' subjective experience of e-cigarettes use following a single, brief exposure period may not capture any longer-term adverse effects or changes in subjective experience over time, especially for first-time users. One hypothesis for potential changes in subjective effects and use of e-cigarettes is the 'honeymoon effect' (Bullen et al., 2013) in which first-time users have a favourable opinion of e-cigarettes initially but that their enthusiasm wanes over time. However this effect has not been documented to date due to the typical research design using a single session of short duration. Another hypothesis is that the perceived effects of e-cigarettes may be more positive with increased use, because inexperienced e-cigarette users may not have an effective vaping technique and fail to achieve significant nicotine delivery. Research has shown that while samples of experienced e-cigarette users achieve significantly higher plasma nicotine levels after using e-cigarettes (Dawkins & Corcoran, 2014; Vansickel & Eissenberg, 2013), inexperienced e-cigarette users often fail to significantly increase plasma nicotine levels (Bullen et al., 2010; Vansickel et al., 2010). Only one study to date has compared nicotine delivery in experienced and inexperienced users. Farsalinos et al. (2015) found that both experienced and inexperienced users obtained nicotine from second-generation e-cigarettes, but experienced users showed a faster

absorption rate and higher plasma nicotine levels. This is important because tobacco cigarettes deliver nicotine very quickly, which potentiates the addictive properties of nicotine (Benowitz, 2010; Henningfield & Keenan, 1993). To date there are no studies that have examined whether the subjective effects of e-cigarette use change over time, and whether the subjective effects reported after a single, brief exposure to e-cigarettes are maintained after extended use.

It is also important to assess whether smokers' subjective ratings of e-cigarettes are related to changes in smoking habits. Rees et al. (2009) proposed that consumer response (including subjective effects) plays a part in determining the likelihood of initial and subsequent use of 'potential reduced exposure tobacco products' – such as e-cigarettes. If e-cigarettes were rated positively, it would be anticipated that e-cigarette use would increase, and regular cigarette use would decrease. In a previous study, we modelled hypothetical demand for e-cigarettes using subjective effects ratings after a brief exposure to e-cigarettes. First-time e-cigarette users sampled four e-cigarettes of varying nicotine contents (0, 6, 12 and 18mg) in a randomised, blinded order and completed the modified Cigarette Evaluation Questionnaire (mCEQ) (Rose et al., 2000) and simulated demand tasks (MacKillop et al., 2008; Tucker, Bullen, et al., 2017a) after each trial period. The mCEQ assesses the reinforcing effects of tobacco-related products on four subscales: Satisfaction (taste and enjoyment factors), Psychological Reward (withdrawal symptom alleviation), Aversion (aversive effects) and Craving Reduction (single item rating of craving for a cigarette). We reported linear nicotine trends on subjective effects whereby Psychological Reward, Aversion and Craving Reduction increased as nicotine increased, while Satisfaction decreased. We found that simulated demand for e-cigarettes was best predicted by a model that combined Psychological Reward (i.e., withdrawal symptom alleviation) and Satisfaction (i.e.,



enjoyment and taste qualities) as predictors (Tucker, Bullen, et al., 2017a). It is important to note that the sample in this study consisted of low-moderate dependent smokers.

In the current study we followed up the sample from Tucker, Bullen, et al. (2017a) to explore the subjective effects of e-cigarettes and patterns of naturalistic smoking and e-cigarette use over two-week periods, using cartridges containing the four different levels of nicotine (0, 6, 12 and 18mg). We aimed to use the predictive model from Tucker, Bullen, et al. (2017a) to predict actual e-cigarette use using subjective effects ratings after a period of two-week experience using e-cigarettes. We planned to test if the subjective effects that predicted hypothetical demand after a single brief exposure in the laboratory (Psychological Reward and Satisfaction) also predicted reported naturalistic e-cigarette use.

#### **7.4. Method**

**7.4.1. Participants.** 35 adult daily smokers were recruited by community and internet advertisement in two New Zealand cities [Christchurch  $n=22$ ; Wellington  $n=13$ ]. All participants had participated in our prior study (Tucker, Bullen, et al. (2017a) and had responded to requests for baseline analysis of cigarette smoking behaviour for two weeks via daily SMS text messaging. They were required to be adult, daily smokers and the following exclusion criteria were applied: pregnant or breastfeeding, currently using nicotine replacement products or smoking cessation medication, and suffering from any acute or chronic respiratory, cardiovascular, hepatic or renal disease.

**7.4.2. Procedure.** After completing the laboratory procedures described in Tucker, Bullen, et al. (2017a), participants took part in an eight-week trial period as outlined below. The study was approved by the Northern B Health and Disability Ethics (HDEC) Committee (15/NTB/56).

Participants' baseline smoking level was assessed for a two week period prior to the sessions using Ecological Momentary Assessment (EMA) (Shiffman, Stone, & Hufford,

2008). Participants responded to one SMS text message per day at a specified time of their choosing, which asked how many cigarettes they had smoked in the last 24 hours.

After completing the laboratory procedures (Tucker, Bullen et al., 2017a), participants received a demonstration and safety briefing before being given a free e-cigarette kit containing a rechargeable e-cigarette (Vype ePen), charger and two weeks' worth of e-cigarette cartridges (Golden Tobacco flavour).

Over the following 8 weeks they used the 0, 6, 12 and 18mg e-cigarette cartridges for a two week period in a randomised, blinded order. Participants were instructed to use the e-cigarette ad libitum for each of the two weeks periods in an attempt to substitute the e-cigarette for use of their regular cigarettes as much as possible. They were not required to quit smoking specifically. Given the observational nature of the study and the intention to monitor the uptake of e-cigarettes as an alternative to regular cigarettes in a real world setting, no emphasis on encouragement, motivation or reward for cessation was provided. Participants were required to respond to one SMS text message per day asking how many cigarettes they had smoked and how many 1-5 minute e-cigarette 'vapes' of the e-cigarette they had had in the last 24 hours. Participants also responded to an online questionnaire at the end of each two week sampling period including subjective effects scales. They were also invited to ask any questions, report any concerns or make any additional comments at this point. No verification of smoking level or cessation was assessed.

**7.4.3. Measures.** The assessment of demographic information and smoking history included age, gender, ethnicity, marital status and number of years smoking. The dependence measures used were the Fagerström Test of Nicotine Dependence (FTND) (Heatherton et al., 1991) and the Glover-Nilsson Smoking Behaviour Questionnaire (GNSBQ) (Glover et al., 2005). The FTND assesses physical nicotine dependence based on the sum of 6 items scored from 0-3 or 0-1 (Heatherton et al., 1991). It has shown good test-retest reliability and internal

consistency (Pomerleau et al., 1994). The GNSBQ uses 18 items scored from 0-4 to assess the cognitive, social and behavioural effects of tobacco dependence. It has shown good internal consistency and test-retest reliability, and is significantly correlated with nicotine craving (Rath et al., 2013).

Subjective effects questionnaires included the Modified Cigarette Evaluation Questionnaire (mCEQ) (Rose et al., 2000), and 8 visual analogue scale (VAS) items about the common adverse effects of nicotine replacement products rated from 1 (not at all) to 10 (extremely). The mCEQ is comprised of 12 items rated from 1 (not at all) to 7 (extremely) assessing the reinforcing effects of smoking on four subscales including satisfaction, psychological reward, aversion and craving reduction (Rose et al., 2000). It has good test-retest reliability and the validity of the multidimensional framework is supported (Cappelleri et al., 2007).

**7.4.4. Data Analysis.** Linear mixed model analyses (IBM SPSS Statistics 22) were used to assess patterns of cigarette smoking and e-cigarette use, and subjective effects of e-cigarettes by nicotine content, and to model e-cigarette use using mCEQ subscales. Plausible covariance-structure models were fitted and the best-fitting model (autoregressive) was selected by model comparison tests (Akaike's Information Criterion) (Akaike, 2014).

## 7.5. Results

**7.5.1. Participant characteristics.** Participant characteristics are shown in Table 6. Of the 35 participants that completed the laboratory session, 28 [80%] participants provided SMS data for at least one cartridge trial and 18 [51%] completed all four trials. Twenty-eight [80%] provided SMS data for trial one, 26 [74%] for trial two, 21 for trial three [60%] and 18 for trial four [51%]. Baseline cigarettes smoked per day did not significantly differ for those that participated in the field trial [ $M=9.69$ ] versus those that dropped out after the laboratory session [ $M=9.45$ ] [ $t(33)=.108, p=.915$ ], or for those that completed all four SMS trials

[ $M=9.49$ ] versus those who partially completed [ $M=10.77$ ] [ $t(24)=.278$ ,  $p=0.783$ ]. Twenty-nine participants [83%] completed at least one fortnightly email, 23 [66%] completed at least two, 19 [54%] completed at least three and 11 [31%] completed all four.

Table 6. Participant characteristics ( $N=35$ )

Demographic	M	SD
Age	26.76	10.61
Gender	%	n
Male	73.3	33
Female	26.7	12
Ethnicity	%	n
New Zealand European	71.1	32
Māori	6.7	3
Other	22.2	10
Cigarette type usually smoked	%	n
Factory-Made	53.3	24
Roll-Your-Own	46.7	21
Smoking information	M	SD
Nicotine dependence (FTND)	3.20	2.52
Behavioural dependence (GNSBQ)	16.96	5.50
Years smoked	9.13	5.50
Cigarettes per day	10.32	6.69

*Note.* FTND = Fagerström Test of Nicotine Dependence, GNSBQ = Glover-Nilsson Smoking Behaviour Questionnaire

**7.5.2. E-cigarette uptake and changes in smoking behaviour.** Figure 14 shows smoking behaviour (cigarettes per day) and e-cigarette use (1-5 minute vapes per day) by cartridge nicotine content (right panel) and cartridge order (left panel). Figure 14 shows that mean cigarettes smoked per day decreased from 9.69 [SD=5.07] during baseline assessment to 6.09 [SD=4.18] when e-cigarettes were provided [ $t(62)=2.751, p=.008, d=.77$ ].

**7.5.2.1. Daily e-cigarette use.** Figure 14 shows that e-cigarette use was higher for the 6, 12 and 18mg nicotine cartridges than for the 0mg nicotine cartridge but that overall e-cigarette use decreased over the eight-week period; mixed model analysis confirmed a significant effect of order [ $F(1, 87.640) = 13.293, p < .001$ ] in which e-cigarette use decreased over time. The main effect of nicotine was not significant [ $F(3, 57.999) = 2.092, p = .111$ ] but planned comparisons showed significantly greater reported daily use of the three nicotine-containing e-cigarette cartridges (6, 12 and 18mg) [ $M=4.50, SD=3.50$ ] compared to the 0mg cartridges [ $M=2.59, SD=2.38; p=.023$ ].

E-cigarette use was quantified as number of 1-5 minute ‘vapes’ (puffs on an e-cigarette). We attempted to validate this measurement with correlation analyses between e-cigarette use via SMS and number of unused cartridges reported via email. SMS self-report was strongly positively correlated with unused cartridges reported via email for 0mg [ $r = -.82; p < .05$ ], 6mg [ $r = -.68; p < .05$ ], 12mg [ $r = -.69; p < .05$ ] and 18mg cartridges [ $r = -.82; p < .05$ ]. Thus it is likely that use self-reported via SMS did reflect the relative magnitude of e-cigarette use across all nicotine levels.

**7.5.2.2. Cigarettes per day.** Mixed model analysis showed that there was no main effect of order [ $F(1, 78.918) = 1.015, p = .317$ ] but there was a significant effect of nicotine [ $F(3, 59.846) = 2.952, p = .040$ ] on cigarettes smoked per day. Contrast analysis showed significantly lower cigarettes smoked per day for 6mg e-cigarette cartridges [ $M=5.77, SD=4.18$ ] than 0, 12 and 18mg cartridges [ $M=6.50, SD=4.84; p=.034$ ]. Planned comparisons

showed no significant differences in cigarettes smoked per day when using nicotine-containing e-cigarette cartridges compared to non-nicotine containing cartridges [ $p=.103$ ].

Correlation analyses showed weak-to-moderate negative correlations between vapes per day and cigarettes per day. Although none were significant [ $ps>.05$ ], correlations increased as nicotine increased [0mg  $r=-.13$ ; 6mg  $r=-.28$ ; 12mg  $r=-.38$ ; 18mg  $r=-.41$ ].

**7.5.3. Subjective effects.** Figure 15 shows average mCEQ subscale scores after participants completed a two week trial using the 0, 6, 12 and 18mg e-cigarettes. Mixed model analysis found no significant order effects for Satisfaction [ $F(1,75.733) = .845$ ,  $p=.361$ ], Psychological Reward [ $F(1,74.117) = .195$ ,  $p=.660$ ], Aversion [ $F(1,74.888) = .060$ ,  $p=.808$ ] or Craving Reduction [ $F(1,75.071) = .100$ ,  $p=.753$ ]. There were no significant main effects of nicotine or linear, quadratic or cubic effects on any of the subscales [ $ps>.05$ ]. Planned comparisons found significantly higher Craving Reduction for nicotine-containing cartridges [ $M=3.51$ ,  $SD=1.39$ ] relative to placebo cartridges [ $M=2.60$ ,  $SD=1.54$ ;  $p=.026$ ], but no significant effects on any of the other subscales [ $ps>.05$ ].

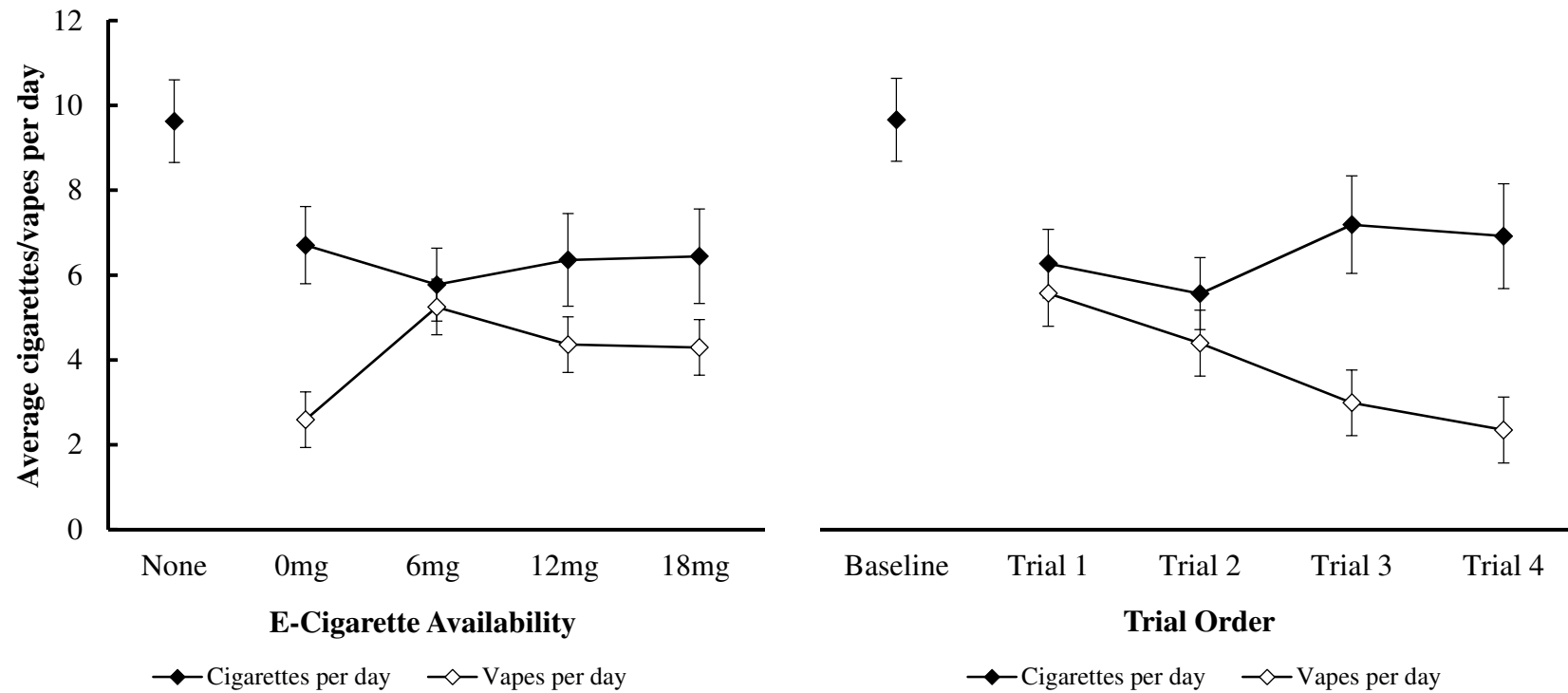


Figure 14. Average cigarettes per day (filled diamonds) and vapes per day (unfilled diamonds) shown separately by cartridge nicotine content (left panel) and trial order (right panel). Baseline cigarettes per day is shown separately. Error bars indicate  $\pm 1$ SE.

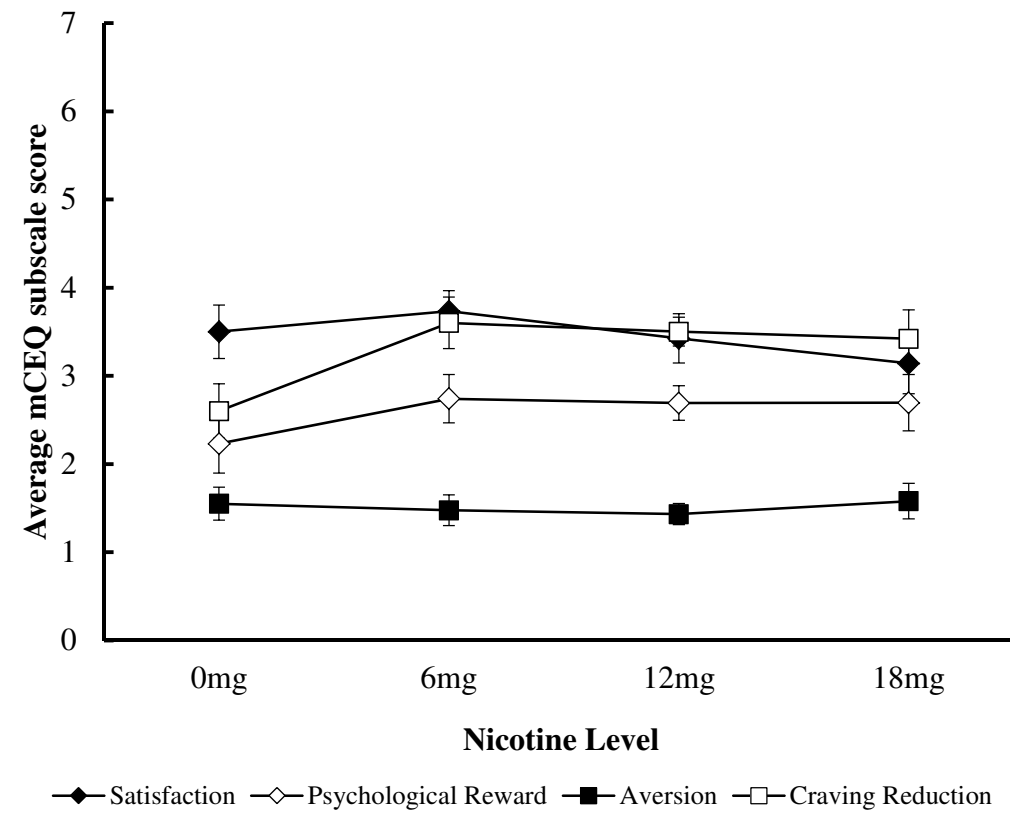


Figure 15. Average mCEQ subscale scores after a two week trial period for 0, 6, 12 and 18mg nicotine content cartridges. Satisfaction (filled diamonds), Psychological Reward (unfilled diamonds), Aversion (filled squares) and Craving Reduction (unfilled squares) are shown separately. Error bars indicate  $\pm 1SE$ .



We conducted correlation analyses on the four mCEQ subscales as rated in the laboratory after first experience and in the field trial after two weeks experience with each cartridge. Overall weak-to-moderate positive correlations were found for the four subscales [Satisfaction  $r=.14$ ; Psychological Reward  $r=.33$ ; Aversion  $r=.18$ ; Craving Reduction  $r=.23$ ]. The strength of the correlations also varied by nicotine level, as shown in Table 7.

Table 7. Correlations coefficients for mCEQ subscales for 0, 6, 12 and 18mg e-cigarette cartridges after first-time experience in the laboratory and after two weeks experience in the field trial.

	0mg	6mg	12mg	18mg	Combined
Satisfaction	.46*	.03	.57*	.51*	.42*
Psychological Reward	.24	.25	.29	.49	.33*
Aversion	.48*	.08	.10	.43	.18
Craving Reduction	.02	.41	.32	.01	.23*

*Note.* Asterisks (\*) indicate significant correlations [ $p<.05$ ].

**7.5.4. Predicting uptake with subjective effects.** An important goal was to test whether the subjective effects associated with simulated demand in the laboratory study (Tucker, Bullen, et al., 2017a) also predicted uptake of e-cigarettes in participants' daily lives. Based on the predictive model in Tucker, Bullen, et al. (2017a) we conducted a mixed model analysis with a best-fitting covariance structure (autoregressive) to predict e-cigarette use using Psychological Reward and Satisfaction mCEQ subscale scores. Psychological Reward and Satisfaction were both significant predictors of e-cigarette use [ $b=.935$ ,  $p=.048$ ;  $b=.841$ ,  $p=.039$ , respectively]. Thus, across nicotine levels, participants' e-cigarette use was positively related to both Psychological Reward and Satisfaction.

We also tested five other 2-factor models using all possible combinations of the mCEQ subscales. Of the six models, the *a priori* model (Psychological Reward and Satisfaction) demonstrated the best model fit based on likelihood ratio comparison tests (Akaike's Information Criterion), and was equal with a model comprised of Craving Reduction and Satisfaction [ $b=.64$ ;  $p=.027$ ;  $b=1.04$ ;  $p=.002$ , respectively].

## 7.6. Discussion

We examined smoking behaviour and e-cigarette use when smokers were provided with 0, 6, 12 and 18mg e-cigarettes, each for a 2-week period. The number of cigarettes smoked was less when e-cigarettes were available relative to baseline, and e-cigarette use was greater when using nicotine-containing cartridges relative to non-nicotine cartridges. Subjective effects analyses showed that nicotine-containing cartridges led to greater craving reduction than non-nicotine cartridges. The other subjective effects (satisfaction, psychological reward and aversion) did not significantly differ depending on nicotine level.

These trends are different from those reported in our previous study which found that for first-time e-cigarettes users, psychological reward, craving reduction and aversion increased as nicotine increased, while satisfaction decreased (Tucker et al., 2017b). In addition, subjective effects in the present study were not strongly correlated with those from the previous study. This was not unexpected. In the present study, the mCEQ was administered as an online survey emailed to participants at the completion of the 2-week trial, with no control over when their last cigarette or e-cigarette use took place. In contrast, in the previous study the mCEQ was administered as a written questionnaire immediately after trialling an e-cigarette in the context of nicotine withdrawal. In addition, in the present study participants had more time to adapt their e-cigarette use technique, which is hypothesised to be an important factor in determining nicotine delivery and thus reinforcing effects (Farsalinos et al., 2015). However it is important to note that we did not assess nicotine

delivery and vaping topography in this study. Therefore, the reasons for changes in subjective effects cannot be determined.

Importantly, despite the changes in nicotine trends for subjective effects from first-time use to longer-term experimental use, the two-factor model that predicted simulated demand for e-cigarettes in our previous study (Tucker, Bullen, et al., 2017a) also predicted actual e-cigarette use in the current study. In this model, psychological reward (withdrawal symptom alleviation) and satisfaction (taste and enjoyment properties) predicted simulated demand for e-cigarettes based on a Cigarette Purchase Task (MacKillop et al., 2008; Tucker, Bullen, et al., 2017a). This model remained the best fitting 2-factor predictive model for self-reported e-cigarette use behaviour in this study, with equal model fit to a 2-factor model of craving reduction and satisfaction. This suggests that the same factors that determine whether a first-time user anticipates that they would purchase e-cigarettes after trial use also predict the extent of actual e-cigarette use during a longer-term period of experimental use, even if the subjective effects themselves change during that time. These findings support the idea that consumer response to e-cigarettes, primarily the positively reinforcing (taste and enjoyment qualities) and negatively reinforcing (reducing of withdrawal symptoms) effects of e-cigarette use, are an important factor in determining subsequent use (Rees et al., 2009). The same factors were important at different stages of the process of deciding to transition from first-time trial use to longer-term experimental use. It would be of interest to monitor whether the same factors predict transition from experimental or initial use to ongoing, long-term e-cigarette use.

Notably, participants used the e-cigarette less over time during the eight-week trial period regardless of nicotine level. This may be consistent with a “honeymoon effect” (Bullen et al., 2013) whereby our sample of first-time users may have engaged in a high level of experimental e-cigarette use, but their enthusiasm reduced over time. A number of factors

may have contributed to this including: reduced novelty and thus enthusiasm, dissatisfaction with the subjective effects of the e-cigarettes themselves, poor e-cigarette vaping technique or topography or dissatisfaction with the flavour of the cartridges. We found no order effects for the subjective effects mCEQ subscales, which suggests that the subjective effects did not significantly decrease over time. However the subjective effects are rated relatively low on the 7-point scale, with mean scores for Satisfaction, Psychological Reward and Craving Reduction indicating that participants rated these items (including enjoyment, taste, satisfaction, reducing withdrawal symptoms and reducing craving) “a little” to “moderately”. Over time the novelty of the e-cigarette may have reduced and the subjective effects may have not been desirable enough to maintain the same level of use. Due to the duration of our study (eight weeks total e-cigarette use) we cannot determine whether use would cease completely in time or whether the initial rates reduced to what may be a lower but constant rate of use over a longer period.

Cigarette smoking was significantly lower during the trial period, when e-cigarettes were available, relative to baseline; suggesting that participants used the e-cigarettes to reduce their cigarette smoking behaviour. This is consistent with survey and experimental studies and clinical trials showing that e-cigarette use was associated with reductions in smoking (Berg et al., 2014; Brown et al., 2014; Bullen et al., 2013; Caponnetto, Auditore, et al., 2013; Caponnetto, Campagna, et al., 2013; Etter & Bullen, 2014; Farsalinos, Romagna, et al., 2014; Polosa, Caponnetto, et al., 2014; Polosa et al., 2011) and supports the use of e-cigarettes for tobacco control or harm reduction. The greatest reductions in cigarettes per day were seen when participants used 6mg cartridges. This is interesting because, although e-cigarette use was not significantly higher than with the 12mg and 18mg cartridges, the properties of the 6mg cartridge appear to have enabled participants to reduce their cigarette smoking to a greater degree than the higher strength cartridges. It is possible that, similar to

our previous study (Tucker, Bullen, et al., 2017a), both relatively high satisfaction and relatively high psychological reward may be necessary for the e-cigarette to meet the needs of the users in this study. The higher nicotine cartridges appear to be less satisfying in Figure 2, and the 0mg cartridge appears to be less effective at reducing withdrawal symptoms and craving. However this is speculative and significant differences in subjective effects were not observed in this study. Additional research with a larger sample size would be required to examine this further.

Some limitations must be acknowledged. It is important to note that the sample in this study was relatively small which was compounded by attrition during the trial. In addition, the sample was comprised of primarily young, male smokers with low-moderate nicotine dependence. This limits generalisation to older, more dependent smokers and females, who have responded more favourably to e-cigarettes in previous studies (Grace et al., 2015c). Also, in accord with our design, the sample were first-time users of e-cigarettes. Thus it is unclear whether the subjective effects identified as important in determining relatively short-term, experimental use of e-cigarettes can also predict longer-term habitual use.

Another potential limitation is that assessment of cigarettes smoked and e-cigarette vaped per day was obtained via self-report EMA by SMS. Self-report methods have been shown to be inaccurate due to the a number of cognitive biases (Hammersley, 1994). Though EMA still requires self-report, it has advantages in that it provides immediate, real-time recording in the participants natural environment (Shiffman, 2009; Shiffman et al., 2008). It is also proposed that EMA is associated with few drop-outs and little missing data; however this was not the case in our study. A potential problem using EMA with e-cigarettes is that it is difficult to quantify use. To date, metrics of e-cigarette use have included puffs per day, periods of use per day, number of cartridges used per day and millilitres of e-liquid used per day (Cooper, Harrell, & Perry, 2016). For simplicity and comparison to regular cigarette

smoking, e-cigarette use was quantified as number of 1-5 minute vapes in this study.

However reported patterns of use have been reported to vary greatly among users and commonly involve shorter but more frequent sessions of use (Cooper et al., 2016; Dawkins, Turner, Roberts, et al., 2013; Pepper & Brewer, 2014). As such our assessment of daily e-cigarette use may not accurately reflect participants' patterns vaping behaviour. A recent study asked e-cigarette users in focus groups what would be the best way to quantify their daily use. Participants reported that individual puffs would be too difficult to measure and that the individual cartridge or e-liquid volume would best reflect their use (Cassidy, Tidey, Colby, Long, & Higgins, 2017). We also asked participants how many unused cartridges they had remaining at the end of each 2-week period and used this to infer number of e-cigarette cartridges used during that period. Strong correlations were found between self-reported cartridges used and self-reported 1-5 minute vapes per day suggesting that while our method may not accurately reflect actual vaping behaviour, it does correspond to relative use across nicotine levels.

To our knowledge this is the first study to describe the subjective effects of e-cigarettes with different nicotine contents for new, low-dependent users with more than a brief, single exposure. Our findings support the idea that response to trialling e-cigarettes is an important factor in determining subsequent experimental and possibly longer-term use (Rees et al., 2009). Enthusiasm for e-cigarettes may decrease over time and as such their availability and pricing should be carefully considered if they are to be more attractive nicotine delivery device than combustible cigarettes; price differentials may be required to encourage uptake.

## 8. GENERAL DISCUSSION

This thesis has described five behavioural economic studies of tobacco control related to price policy, alternative products and the application of these concepts to the tobacco control context in New Zealand. Each chapter has included a discussion of the findings, their relationship to previous research, limitations and implications. In this chapter the major themes and findings of all five studies will be outlined including the role of behavioural economics in tobacco control research, the specific implications of these studies for price policy and alternative products, and the implications for New Zealand in the context of the Smokefree 2025 goal and for reducing inequalities in smoking outcomes for Māori and Pacific Island populations. Limitations and recommendations for future research will also be highlighted before the overall conclusions are outlined.

### 8.1 The Role of Psychology and Behavioural Economics in Tobacco Control Research

Economic models and analyses have played the predominant role in guiding tobacco price policy, one of the most fundamental and successful policies implemented worldwide (Chaloupka et al., 2011; Chaloupka et al., 2012; Dunlop et al., 2011; Gallet & List, 2003; Gallus et al., 2006; Hanewinkel & Insensee, 2006). However, by incorporating principles from psychological theory and experimental design, behavioural economic studies can make an important contribution to our understanding of addiction and tobacco control. Behavioural economic methods can generate price and consumption data over a broader range than can be assessed in the natural economy, provide a platform to evaluate the potential impact of introducing alternative products onto the market, compare important groups, and evaluate intra-individual differences in demand and addiction to better understand addiction processes and devise better interventions. Tobacco control research must take into account the dynamic global context in which policies are being implemented, including proposals for endgame goals in a number of countries and the rapid development of and increasing access to

alternative products. Behavioural economics provides a time- and cost-effective approach for evaluation of such changes, and there is a growing evidence base for the validity of behavioural economic measures and methods.

**8.1.1. Measuring demand for cigarettes.** The research in this thesis provides additional support for the use of the CPT (MacKillop et al., 2008) for assessing demand for cigarettes. The demand curves generated by the CPT reported in Chapters 4 through 6 were characteristic of demand curves for inelastic commodities, with cigarette consumption mostly high but decreasing sharply at relatively high prices and eventually reducing to zero (Tucker et al., 2017; Tucker, Bullen, et al., 2017a; Tucker, Kivell, et al., 2017). This is consistent with the demand curves seen in previous studies using the CPT (Chase et al., 2013; Few et al., 2012; Johnson & Bickel, 2006; MacKillop et al., 2012; Mackillop et al., 2016; MacKillop et al., 2008; Murphy et al., 2011) and also with self-administration studies (Bickel, Degrandpre, Higgins, & Hughes, 1990; Bickel, Degrandpre, Hughes, & Higgins, 1991a; Bickel & Madden, 1999; Johnson & Bickel, 2006). The exponentiated demand model (Koffarnus, Franck, et al., 2015) provided good fits to the demand data generated in all of these chapters (Tucker et al., 2017; Tucker et al., 2017a; Tucker, Kivell, et al., 2017) and demand metrics generated directly from the CPT and from fits of the exponentiated model highlighted relevant group differences for Māori/Pacific and New Zealand European smokers (Tucker, Kivell, et al., 2017). This was consistent with the greater reductions in cigarette consumption by Māori/Pacific smokers, especially males, reported after actual excise tax increases in New Zealand (Tucker et al., 2016). Although these two findings were not directly compared, Grace et al. (2014) found that a measure of local elasticity of demand derived from the CPT predicted actual changes in smoking behaviour after excise tax increases in the same sample, though they did not assess this by ethnicity. This supports that the CPT can provide



information about group differences in cigarette demand that may be used to evaluate the effectiveness of price policy for specific groups.

**8.1.2. Measuring demand for alternative products.** The studies in this thesis used simulated demand procedures to evaluate demand for alternative products, including an adapted CPT, which evaluated demand for the alternative product if available in isolation, and a cross-price task evaluating demand when available concurrently with regular cigarettes, but at a lower price. Previous research supports that hypothetical demand corresponds with actual purchasing and substance use behaviour (Amlung et al., 2012; Amlung & MacKillop, 2015; Bickel et al., 2009; Johnson & Bickel, 2002; Lagorio & Madden, 2005; MacKillop, Amlung, et al., 2010; Madden et al., 2003; Madden et al., 2004; Wilson et al., 2016). The validity of the CPT is well supported for regular cigarettes (Chase et al., 2013; Few et al., 2012; Grace et al., 2014, 2015a; MacKillop et al., 2014; MacKillop et al., 2012; MacKillop et al., 2016; MacKillop et al., 2008; Murphy et al., 2011). The research in this thesis is among the first to use a CPT to evaluate demand for alternative products: VLNC cigarettes (Tucker et al., 2017) and e-cigarettes (Tucker, Bullen, et al., 2017a).

Because VLNC cigarettes are virtually identical to regular cigarettes in their intended use and units for sale, it seems likely that the CPT would be a valid way in which to assess demand for these products. Conceptually, it may be anticipated that estimated consumption of VLNC cigarettes would be higher than for regular cigarettes, in an attempt to achieve optimal nicotine intake from a product containing a substantially lower dose. However, the opposite was found in Chapter 5; estimated consumption of VLNC cigarettes was lower (Tucker et al., 2017). This may indicate that preference and favourability may play a more important role in smokers' decision to use these products, but it must be considered that the single use of VLNC cigarettes may have been insufficient for participants to make informed choices on the CPT and so estimates of demand may not be accurate. Nonetheless, there could be important

policy implications based on the simulated demand data, which are discussed in the next subsection.

It is less clear when the CPT is an appropriate way in which to assess demand for e-cigarettes due to more substantial differences in the product characteristics, patterns of use and units of pricing. E-cigarettes are ‘vaped’ in quite different patterns to cigarette smoking (Cooper et al., 2016; Dawkins, Turner, Roberts, et al., 2013; Pepper & Brewer, 2014) and involve a greater upfront cost for the e-cigarette itself and technical accessories, however prices range considerably for the e-liquid or cartridges. Thus, price “per 1-5 minute vape” which was used in attempt to provide an easier comparison with regular cigarettes for first-time e-cigarette users in Chapter 6 (Tucker, Bullen, et al., 2017a) is not likely to be the most realistic way to estimate vaping behaviour based on actual market costs. Cassidy et al. (2017) conducted focus groups with e-cigarette users and found that smokers reported that the relevant unit would be either price per cartridge or per measurement of e-liquid in millilitres (based on the different types of e-cigarettes used). However, it seems unlikely that this could be accurately estimated for first-time users who have no experience of how long such measures would last. Although the unit used in Chapter 6 may not accurately capture patterns of use, results reported in Chapter 7 suggest that the mean number of ‘1-5 minute vapes per day’ reported (pertaining to actual daily e-cigarette use) corresponded with reported remaining cartridges at the end of the two week period (Tucker, Bullen, et al., 2017b). This provides some tentative support for the simulated demand estimates for e-cigarettes generated by the CPT.

The studies in this thesis use a cross-price task from Grace et al. (2015b) to estimate cross-price elasticity for VLNC cigarettes and e-cigarettes. It is important to note that the CPE was based on a limited range and density of prices and may not have accurately estimated the shape of the function. As discussed in Chapter 5 (Tucker et al., 2017a), Hursh

and Roma (2016) proposed an extension of the exponential equation for fitting CPE which may provide a more accurate estimate of CPE based on a greater number of prices. However, the prices used here encompassed a relatively realistic range of prices (based on the New Zealand market price of cigarettes at the time of the study) and similar CPE estimates were found in Chapters 4 (Tucker, Kivell, et al., 2017), 5 (Tucker et al., 2017) and 6 (Tucker, Bullen, et al., 2017a) to those based on self-administration studies (Johnson & Bickel, 2003; Johnson et al., 2004; Shahan et al., 2000). This suggests that the CPE estimates obtained in this thesis may provide important information about the substitutability of these alternative products, though should be interpreted with caution.

**8.1.3. Utility of subjective effects measures.** Rees et al. (2009) propose that the commercial success of alternative products depends in part on consumer response to trialling and using these products. The aspects of consumer response considered in this thesis include various subjective effects, specifically Satisfaction (taste and enjoyment qualities), Psychological Reward (withdrawal symptom alleviation), Aversion, and Craving Reduction. The studies in this thesis highlight the importance of considering the subjective effects of these products. In Chapter 5, the lower demand for VLNC cigarettes (relative to regular cigarettes) corresponded with poorer subjective effects ratings, suggesting that these factors may be a barrier to consumer use of VLNC cigarettes if they were to become available (Tucker et al., 2017). The studies in Chapters 6 and 7 showed that although subjective effects may change over time, both simulated demand and actual e-cigarette use behaviour can be predicted using a 2-factor subjective effects model (Psychological Reward and Satisfaction) (Tucker, Bullen, et al., 2017a, 2017b). This suggests that subjective effects may be an important factor in determining subsequent use of a product and may be important factors to study, particularly in the current context where multiple alternative products are becoming more and more available and accessible for smokers.

## 8.2. Strengths and Limitations

As mentioned previously, the strengths of behavioural economic methods include the broad range of price and consumption data that can be assessed, the platform for direct comparison of alternative products, ability to compare important groups, and ability to evaluate intra-individual differences (MacKillop et al., 2012). Furthermore, the strengths of hypothetical purchase tasks over traditional self-administration studies include no necessary increased use of a potentially harmful substance for purposes of data collection, reduced participants demands and the time- and cost-efficiency (Reed et al., 2014). Although hypothetical purchase tasks rely on estimated, self-reported consumption, studies suggest that hypothetical responding corresponds with actual behaviour in delay discounting studies (Bickel et al., 2009; Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden et al., 2003; Madden et al., 2004) and with an alcohol purchase task (Amlung et al., 2012; Amlung & MacKillop, 2015; MacKillop, Amlung, et al., 2010). As stated, the studies in this thesis highlight the usefulness of behavioural economic methods and simulated demand tasks for the study of tobacco control policies.

The limitations of the individual studies are described in the discussion sections of the empirical chapters and will not be repeated here. However, some common overall limitations can be noted here. The studies in this thesis have relatively small sample sizes, and the samples in the laboratory studies were fairly young with relatively low nicotine dependence (Tucker et al., 2017; Tucker, Bullen, et al., 2017a). The results therefore may not generalise to older smokers or those with higher nicotine dependence. The participants were also predominantly of New Zealand European descent, and there were not enough Māori or Pacific Island participants to compare results by ethnicity in these laboratory studies. In addition, the Māori/Pacific sample in Chapter 3, 4 and 5 (Tucker et al., 2017; Tucker, Kivell, et al., 2017a, 2017b) was combined due to the sample size and low numbers of Pacific Island

participants. Although both groups have elevated smoking prevalence and low socioeconomic status (Ministry of Health, 2009; Salmond et al., 2012; Statistics New Zealand, 2014a), they are unlikely to represent a truly homogeneous group and aggregation may obscure subtle differences. Research with larger, more representative samples would allow more comprehensive analysis of between group differences that may provide insight into the smoking behaviour of these groups and their reactions to potential policies.

Despite some limitations, the research in this thesis supports that behavioural economics may be a useful framework for the analysis of the rapidly changing regulatory context in tobacco control and may provide important individual-level data about smoking-related behavioural change not captured using macroeconomic data. In this way, behavioural economic and psychological studies of price policy and alternative products may have important implications for tobacco control policy. The implications of the studies in this thesis for tobacco control policy will be outlined in the following subsection.

### **8.3. Implications for Tobacco Control Policy**

**8.3.1. Utility and policy implications for price policy.** Internationally, excise tax policy is regarded as the most effective single tobacco control measures available and is supported by a wealth of economic research (Chaloupka et al., 2011; Chaloupka et al., 2012; Dunlop et al., 2011; Gallet & List, 2003; Gallus et al., 2006; Hanewinkel & Insensee, 2006). The studies described in Chapters 3 (Tucker et al., 2017) and 4 (Tucker, Kivell, et al., 2017) of this thesis provide some additional support for this strategy based on both survey data following two annual 10% tobacco excise tax increases in New Zealand and based on self-report data from a Cigarette Purchase Task.

Although actual quit rates were low and hypothetical breakpoints (price that would result in cessation) were fairly high (Tucker et al., 2016; Tucker, Kivell, et al., 2017, ), the magnitudes of the reductions in cigarettes smoked per day were promising [mean cigarettes

per day reduced by 46%]. For smokers who are either unwilling or unable to quit, reduction has been proposed as a harm reduction strategy (Shiffman et al., 2002; Stratton et al., 2001). Although reduction produces only modest reductions in risk of disease (Pisinger & Godtfredsen, 2007), there may be indirect health benefits by motivating cessation. Evaluation of tobacco control programs in the US showed that cigarette consumption (based on sales data) typically declines prior to reductions in smoking prevalence, suggesting that the implementation of tobacco control policies first reduces cigarettes smoked per day before reducing prevalence (Hughes & Carpenter, 2006; Pierce et al., 1994; U.S. Department of Health and Human Services, 2000). Additionally, reviews of controlled, cohort, case-control and experimental studies showed that smokers who reduce their daily cigarette consumption are more likely to quit smoking in the future, and also supported a dose-response relationship whereby greater reductions are more likely to lead to cessation (Begh et al., 2015; Hughes & Carpenter, 2006; Hyland et al., 2005; Klemperer & Hughes, 2016). Hughes and Carpenter (2006) propose two possible reasons: first that reduction may be thought of as a step towards cessation which increases self-efficacy toward the ultimate task and makes success more likely, and second that nicotine dependence may decrease with reduction, thus reducing a barrier to cessation. Thus, changes to patterns of smoking behaviour observed and estimated in this thesis may lead to increased likelihood of cessation success in the future. Longitudinal mediation analyses would be needed to more directly test the mechanism by which price policy leads to cessation. Smoking reduction may play a role, and additional factors may also be considered. Behavioural economic factors such as demand metrics generated from the CPT and exponentiated model, or psychological factors such as smoking dependence (DiFranza et al., 2009; Glover et al., 2005; Heatherton et al., 1991) or stages of change (Diclemente et al., 1991) may provide further insight into the mechanism by which price policy leads to cessation.

**8.3.1.1. Implications for price policy in New Zealand.** The relatively low rates of cessation reported (Tucker et al., 2016) and high breakpoints simulated for both Māori/Pacific and New Zealand European smokers (Tucker, Kivell, et al., 2017) are consistent with simulation studies. These models show that smoking prevalence in New Zealand is unlikely to reach the desired  $\leq 5\%$  rate by 2025 based on the existing rate of increasing excise tax by 10% each year, especially for Māori/Pacific smokers (Cobiac et al., 2015; Ikeda et al., 2013; van der Deen et al., 2014). Elevated smoking prevalence hinders Māori and Pacific Island development aspirations and opportunities through premature death, smoking-related illness, and the erosion of economic, social and cultural wellbeing (Māori Affairs Committee, 2010). Achieving reductions in smoking prevalence among Māori and Pacific peoples, specifically for Māori women who have the highest smoking prevalence (Ministry of Health, 2015), is of vital importance to reduce health inequalities and achieve the national public health goal of a smokefree society (Edwards et al., 2009; Ministry of Health, 2004). Although similar quit rates were found for Māori/Pacific and New Zealand European smokers (Tucker et al., 2016), the greater reductions in cigarette consumption and greater price sensitivity based on the CPT (Tucker, Kivell, et al., 2017) suggests that excise tax policy may prompt greater behavioural change for Māori/Pacific smokers, particularly males. This supports continuing to use price policy to reduce tobacco consumption for Māori/Pacific smokers, especially males, and suggests that this strategy may be particularly effective at reducing smoking for this population. In this way, price policy could help reduce inequalities in smoking prevalence and smoking-related health outcomes in New Zealand.

Price policy is one strategy within a comprehensive tobacco control programme operating within a changing social context driving towards a national goal to be smokefree ( $<5\%$  prevalence) by 2025, and to reduce inequalities in smoking prevalence between Māori and Pacific Island New Zealanders and those of European descent. Overall, price policy alone

appears unlikely to achieve the rapid reductions required to achieve the Smokefree 2025 goal, particularly for Māori/Pacific smokers. Other strategies are likely to be required alongside price policy to reduce smoking behaviour. These additional strategies are particularly important for Māori females, who have the highest smoking prevalence (Ministry of Health, 2015) and appear not as responsive to price increases as their male counterparts.

**8.3.2. Utility and policy implications of VLNC cigarettes.** Due to minimal levels of nicotine, the primary addictive component of tobacco, VLNC cigarettes theoretically deliver reduced levels of the positive and negative reinforcing effects of nicotine. Thus, VLNC cigarettes do not offer any direct health benefits, but instead are likely to reduce nicotine intake and thus dependence, which theoretically should make quit attempts more successful.

Their partial substitutability suggests that some smokers may opt to use VLNC cigarettes if they were made available alongside regular cigarettes at a discounted price. This could improve health outcomes via the mechanism outlined above. However the study in this thesis found low rates of positive CPE and comparably low demand and relatively negative subjective ratings (Tucker et al., 2017). These findings, alongside high rates of non-compliance with VLNC cigarettes in a clinical trial (Donny et al., 2015), suggest that uptake of VLNC cigarettes in an open market when competing against regular cigarettes is likely to be limited. To encourage use of the less preferred VLNC cigarettes over regular cigarettes considerable price differentials would be required. In Chapter 5, the greatest substitution of VLNC cigarettes for regular cigarettes was observed where regular cigarette price was significantly higher than current market price, while VLNC cigarette price was substantially lower than current market price (Tucker et al., 2017). This could be achieved by applying a lower excise tax rate to VLNC cigarettes than regular cigarettes which could have a dual role of reducing nicotine intake and also reducing the financial burden of excise tax increases on



smokers unwilling or unable to quit (Laugesen, 2012). However, even with large price differentials, smokers may complement their use of cheaper VLNC cigarettes with more expensive but preferred regular cigarettes. Though this may still lead to large reductions in nicotine intake, the intermittent pairing of cigarette smoking with the rapid reinforcing effects of nicotine is likely to maintain or potentially even increase cigarette smoking behaviour (Skinner, 1956) and the associated long-term health concerns.

The largest and fastest benefits would be likely to be seen if a mandatory nicotine reduction policy were implemented whereby all combustible cigarettes were required to contain substantially less nicotine ( $<0.05\text{mg}$ ) (Benowitz & Henningfield, 1994, 2013; Donny et al., 2014). A nicotine reduction proposal has been recommended for consideration by the World Health Organisation Study Group on Tobacco Product Regulation (World Health Organization, 2015). This would be likely to have significant public health benefits: a simulation model found that if nicotine reductions were mandated in the US, smoking prevalence would be likely to reduce from 23% to 5% and be associated with significant national public health gains (Tengs, Ahmad, Savage, Moore, & Gage, 2005). Some concerns regarding this proposal include: implementing and enforcing the policy; negative responses from smokers; and the limited research base on VLNC cigarettes (Kozlowski, 2016). With regard to concern that the policy would be viewed negatively, it is true that the study in this thesis and previous research suggest that VLNC cigarettes are experienced as less positive than regular cigarettes. However, survey studies in the US (Connolly, Behm, Heaton, & Alpert, 2012; Fix et al., 2011; Pearson, Abrams, Niaura, Richardson, & Vallone, 2013) and in New Zealand (Li, Newcombe, & Walton, 2016) have shown support for regulations reducing the nicotine in cigarettes from the general public and from smokers. Nonetheless, if the policy were implemented, it would be important to continue to evaluate public response and monitor contraband and smuggling (Kozlowski, 2016). Laugesen (2012) proposed that the New

Zealand government could develop a well-resourced ongoing programme of regular and random laboratory testing of cigarettes for nicotine content to enforce the policy with amendments to the Smoke-free Environments Act (1990).

Although there appears to be some support for VLNC cigarettes, due to the reduced reinforcing effects it is likely that many smokers would seek nicotine elsewhere. Benowitz, Donny, and Hatsukami (2017) argue that successful nicotine reduction policy must be accompanied by providing readily available, consumer-acceptable non-combusted forms of nicotine to support shifting the source of nicotine from the most harmful to less harmful products, such as e-cigarettes. Though these approaches are often discussed independently, a combination of the two approaches is likely to have the greatest impact. The following subsection will outline the findings and implications of the studies in this thesis on e-cigarettes, before discussing the potential for combining these two strategies.

**8.3.3. Utility and policy implications of e-cigarettes.** E-cigarettes could provide a safer source of nicotine for smokers to use instead of extremely harmful tobacco cigarettes, allowing smokers to make the decision to attain the reinforcing effects of nicotine by other means. They may have benefits over common NRT products by addressing both the positive and negative reinforcing effects of nicotine and also providing some sensory and motor cues that may have become conditioned reinforcers. The studies in this thesis support that nicotine may play an important role in determining the subjective effects of e-cigarettes and their subsequent use, but highlights that taste and enjoyment factors also play an important role, and these factors may be negatively affected by higher levels of nicotine (Tucker, Bullen, et al., 2017a). Based on these findings, higher levels of nicotine in e-cigarettes may not be required for low-moderate dependence smokers to attain the positively and negatively reinforcing effects of nicotine and, in fact, higher levels may be experienced as more aversive by low-dependent, first-time users and may discourage future e-cigarette use. This suggests

that lower nicotine levels may provide these users with the optimal balance of withdrawal symptom alleviation and taste and enjoyment factors to promote the transition from first-time trial use to experimental or potentially longer-term use of e-cigarettes. Educational campaigns may assist with this process. However it is important to note that the sample in these studies was predominantly young and male, with relatively low levels of dependence. It would be important to assess these trends in highly dependent smokers in order to determine whether the same increase in aversiveness with increasing nicotine content would be observed, whether the predictive model would remain significant, and which nicotine levels would be most beneficial in their decision to switch to e-cigarettes.

Another important finding is that e-cigarette use decreased over the course of the eight-week field trial. Due to the brevity of the trial reported in this thesis (Tucker, Bullen, et al., 2017b) it is unclear whether e-cigarette use would have ceased entirely over time, or stabilised at a lower level. The reductions in use may be attributed to changes in novelty or subjective effects (Kong, Morean, Cavallo, Camenga, & Krishnan-Sarin, 2015), or factors related to the methodology such as the single flavour provided (Farsalinos et al., 2013) and the requirement that participants had to use all of the different nicotine levels over the eight-week trial period. Having more independence with regard to using preferred flavours and nicotine content may encourage higher or more stable use over time. Naturalistic prospective studies would clarify this, but these studies could not be conducted in New Zealand specifically until nicotine-containing e-cigarettes are legalised. Nonetheless, additional strategies may be required to encourage ongoing use of e-cigarettes and prevent relapse to smoking or increased cigarette consumption.

Results in Chapter 6 showed that e-cigarettes with cartridges of all nicotine levels functioned as partial substitutes for regular cigarettes (Tucker, Bullen, et al., 2017a) suggesting that their availability could reduce cigarette smoking. However, combining e-

cigarettes with other tobacco control mechanisms is likely to lead to greater benefits. One example of this is using a price differential to encourage switching (Wilson et al., 2015). This strategy is supported by the study in this thesis which found a positive CPE, indicating that as regular cigarette price increased, e-cigarette use increased and regular cigarette use decreased. Price differentials may be implemented in a number of ways. Wilson et al. (2015) suggest applying excise tax increases to regular cigarettes but taxing e-cigarettes only with routine Goods and Services Tax (GST). Chaloupka et al. (2015) suggest applying different levels of excise tax to each product based on their risk profiles to encourage switching from regular cigarettes to e-cigarettes but keeping the price high enough to discourage initiation in young people or non-smokers. Another alternative may be for the Government to subsidise e-cigarettes as a Nicotine Replacement Therapy (NRT) in the same way that nicotine patches and gum are often subsidised. This may be combined with additional education campaigns providing accurate information about the relative health risks (McNeill et al., 2015), on the optimal and safe use of e-cigarettes, and potentially encouraging relatively low nicotine levels for first-time users.

**8.3.3.1. *E-cigarettes and tobacco control in New Zealand.*** As stated previously, price policy alone is unlikely to achieve the rapid reductions required to achieve the Smokefree 2025 goal in New Zealand, particularly for Māori/Pacific smokers. E-cigarettes have been proposed to be an attractive option for New Zealand smokers' (Fraser, Chee, & Laugesen, 2016; Glover & McRobbie, 2015; Guiney, Li, & Walton, 2015; Li et al., 2013) but their current legal status in New Zealand restricts access to e-cigarettes that deliver nicotine. The studies in this thesis find that nicotine may play a role in determining the subjective effects of e-cigarettes and their subsequent use, which supports the Ministry of Health (2017) proposal to regulate nicotine-containing e-cigarettes as consumer products. This proposal would substantially increase access to e-cigarettes as an alternative product, especially for

lower-income smokers or those without credit cards in order to purchase nicotine-containing e-liquid online. This may have particularly significant implications for Māori/Pacific smokers, who were found to be more price sensitive and also rated e-cigarettes more favourably than New Zealand European smokers (Tucker, Kivell, et al., 2017). As demonstrated in Chapters 6 and 7, more favourable subjective effects ratings may increase demand for e-cigarettes and ongoing use (Tucker, Bullen, et al., 2017a, 2017b). However the study in Chapter 4 only used a simple, single-item measure of satisfaction and did not specifically model the relationship between subjective effects and demand for Māori/Pacific smokers. Further research with a representative sample would be needed to examine the subjective effects of e-cigarette use in more detail and to test the predictive model in this population.

Making e-cigarettes available at a lower price than regular cigarettes may be particularly effective at reducing demand for regular cigarettes and encouraging use of e-cigarettes. This combination could be particularly effective for Māori/Pacific males, who were found to be more price sensitive than Māori/Pacific females. Due to lower levels of nicotine dependence and higher importance of social, cultural and behavioural cues for Māori/Pacific females (Tucker, Kivell, et al., 2017), nicotine in e-cigarettes may not be the most important factor. This may raise the question of why non-nicotine e-cigarettes have not been successful in reducing smoking prevalence for Māori/Pacific females thus far. It may be that social and environmental change would be required before e-cigarettes became an attractive alternative for Māori/Pacific females. Educational campaigns targeted at Māori/Pacific females, and encouraging switching to e-cigarettes for Māori/Pacific males using price mechanisms, may help change the social interactions, cues and determinants of smoking and e-cigarette use for this population.

#### **8.3.4. Implications for a comprehensive nicotine and tobacco control policy.**

Although the mechanisms by which VLNC cigarettes and e-cigarettes could reduce smoking behaviour are vastly different, it has been proposed that they could complement one another. If both VLNC cigarettes and e-cigarettes were available alongside regular cigarettes, they could each compete with regular cigarettes and provide smokers with alternative products. VLNC cigarettes could break the association between cigarette smoking and the direct reinforcing effects of nicotine, while e-cigarettes with nicotine could form a new association between the reinforcing properties of nicotine and the alternative and less harmful product. However, if regular cigarettes were still available, smokers may choose not to use these less preferred products, or use them to complement their use of regular cigarettes. Price policy could be used in combination with the available products to encourage switching, however the clear preference for tobacco cigarettes suggest that substantial price differentials may be required.

It has recently been proposed that these strategies could operate together most effectively in a comprehensive, integrated nicotine and tobacco policy where all cigarettes sold are required to contain very low levels of nicotine, and alternative, acceptable forms of nicotine such as e-cigarettes are available (Benowitz et al., 2017; Donny et al., 2016). By mandating substantial reductions in the nicotine content of combustible cigarettes and thus reducing their reinforcing effects, whilst simultaneously making e-cigarettes available, this policy is likely to encourage smokers to make the decision to quit smoking combustible cigarettes. At the same time, mandating nicotine reduction for all combustible cigarettes would be anticipated to reduce dual use, because cigarettes would provide reduced reinforcing effects and thus be less desirable, while e-cigarettes could deliver reinforcing effects and be more satisfying in comparison (Benowitz et al., 2017). Mandatory nicotine reduction would also address some of the controversy surrounding the acceptability of e-

cigarettes within the general public and the tobacco control community (Benowitz et al., 2017). The concern that e-cigarettes could act as a gateway to smoking would be alleviated when the only cigarettes available have low addictive potential, and regulations such as those proposed in New Zealand could limit sale of addictive e-cigarettes to minors and thus minimise uptake by youth (Ministry of Health, 2017). Additional restrictions for sale to minimise uptake by youth and non-smokers could be to only permit sale at pharmacies, by prescription, or provision from clinicians providing smoking cessation services (Wilson et al., 2015). Although it is important to regulate e-cigarettes for factors such as toxicity, safety, and limiting youth uptake, the studies in this thesis highlight that it is important not to disrupt the features of e-cigarettes that make them viable alternatives to cigarettes, including nicotine and characteristics that produce positive subjective effects (Tucker, Bullen, et al., 2017a, 2017b).

Donny et al. (2016) proposed that potential changes to e-cigarette regulation in New Zealand offer a unique opportunity to implement this novel, integrated policy to decouple the link between nicotine and combusted tobacco and make progress towards the Smokefree 2025 goal. Donny et al. (2016) highlight that New Zealand's existing comprehensive tobacco control programme and cessation support could facilitate the implementation and evaluation of such a policy, and the policy has the support of tobacco control advocates, smokers and non-smokers, including priority population groups such as Māori and Pacific Island peoples (Li et al., 2016). It would be important to closely monitor and conduct both medical and scientific research, and to use econometric, behavioural economic and psychological methods to understand the impact of these policies in actual communities and for different groups.

#### **8.4. Future Directions**

The research in this thesis provides some support for the use of behavioural economic and psychological methods for evaluating tobacco control policy, and has implications for

continuing price policy, making nicotine-containing e-cigarettes available, and promoting VLNC cigarettes to reduce nicotine dependence; and the potential combination of these policies has been discussed. The techniques and measures used to generate simulated demand data are relatively new and changing rapidly, particularly for novel products with different patterns of use and pricing like e-cigarettes (Cassidy et al., 2017). It is important to continue to test modified versions of these tasks in order to determine the optimal framing of a CPT or cross-price task for e-cigarettes for both first-time users and more experienced users. This is also likely to change over time due to the rapidly changing e-cigarette market, and it is important for research to be responsive to these changes. Other developments include the Experimental Tobacco Marketplace (ETM); where participants make hypothetical weekly purchases from an experimental online store displaying information and prices for a number of tobacco products (Quisenberry et al., 2016). This mimics a real-world marketplace, allows the manipulation of prices of all products, and can compare demand for a number of products available concurrently. It could provide a useful, practical and relevant way to evaluate the potential combined impact of making VLNC cigarettes and e-cigarettes available alongside, or instead of, regular cigarettes at a range of prices. It would also be useful to use a broader range of prices to estimate CPE and the Hursh and Roma (2016) equation to fit CPE could provide a more accurate estimate of CPE and provide relevant, practical information about the magnitude of price differentials required to encourage e-cigarette or VLNC cigarette uptake. It would also be informative to evaluate subjective effects, demand and CPE for VLNC cigarettes and e-cigarettes alongside one another in an attempt to inform the potential outcomes of a comprehensive, integrated policy. For example, in order for the two products to end tobacco smoking as per the proposed mechanism outlined in section 8.3.4., more favourable outcomes and increased demand for e-cigarettes relative to VLNC cigarettes would be anticipated, in order to fade out tobacco smoking in favour of e-cigarettes as a



source of nicotine. Hypothetical demand tasks or ETM's provide a platform from which to compare these potentially complementary products and may be an important part of evaluating the potential impact of the combined strategy.

As well as continuing to develop appropriate behavioural economic strategies, there is opportunity to validate these against actual behaviour as novel products become introduced to the New Zealand market. Close surveillance of aggregate data and thorough, regular surveys would provide information about actual sales, purchasing and use of both regular cigarettes and novel products. These could be compared with behavioural economic estimates to validate the use of this flexible, time- and cost-efficient approach. The combination of these approaches could provide rich, robust data to evaluate the effectiveness of the proposed policies for the population as a whole and for priority groups; and to use intra-individual differences to anticipate which individuals would be the most responsive, and who may require additional support.

One of the key findings in this thesis was that the predictive model of Psychological Reward and Satisfaction predicted both simulated demand after first-time use and short-term use over a two-week period. Longitudinal research with a larger sample could examine whether this model could predict longer-term e-cigarette use and smoking or cessation behaviour. This would highlight relevant product characteristics that could encourage the transition from the most harmful product to an acceptable and accessible form of nicotine delivery. Studies could also include other components of the Rees et al. (2009) consumer response model to determine which expectations, perceptions and responses best predict uptake at each stage of the transition from never use to trial, experimental use and ongoing use.

## 8.5. Conclusions

The overall aims of this thesis were to use a behavioural economic approach to understand how tobacco control strategies such as tax policy and alternative products may contribute to a comprehensive and integrated nicotine and tobacco policy in New Zealand. Support was found for the use of psychological and behavioural economic methods to generate useful data that can inform policymakers about the potential impact of new policies related to price and alternative products, compare important groups, and even predict how individuals may respond to particular products. These strategies are likely to be particularly useful for informing policy in the rapidly changing global tobacco control context, including in anticipation of the endgame goals, and the rapid development of and increasing access to alternative products. Behavioural economics provides a time- and cost-effective approach for evaluation of such changes, and the research in this thesis contributes to a growing evidence base for the validity of behavioural economic measures and methods.

The findings supported the continuing use of price policy to reduce cigarette smoking behaviour in New Zealand, and highlighted the potential for this strategy, and the availability of e-cigarettes, to reduce smoking inequalities between New Zealand European and Māori/Pacific smokers. This research also supported the proposal to make nicotine-containing e-cigarettes available in New Zealand, and highlighted the importance of product characteristics for subjective effects and subsequent use of e-cigarettes. The findings also supported that VLNC cigarettes have the potential to function as partial substitutes for regular cigarettes, but subjective effects data suggested that additional, intensive strategies would likely be needed for smokers to substitute this less-preferred product for their regular cigarettes. Overall, these studies provide some support for price policy and access to alternative products as independent strategies, but also highlight that the effects may be limited in isolation. In combination, price, nicotine reduction and e-cigarette availability are

likely to provide the greatest and fastest changes in smoking behaviour as a comprehensive nicotine and tobacco control policy that uses price differentials to encourage transitions to less harmful products, and uses the combination of nicotine reduction and e-cigarettes to break the link between the reinforcing effects of nicotine and combustible cigarettes. Due to changing regulations in New Zealand and a strong existing comprehensive tobacco control programme, there may be the opportunity to implement and evaluate potentially groundbreaking strategies in pursuit of the tobacco endgame. Behavioural economics is a useful framework to study addiction, demand, subjective experience and behaviour in the changing context of tobacco control as we approach a smokefree New Zealand.

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## Appendix 1: Publications and Conference Proceedings

### Publications Associated with This Thesis

**Tucker, M. R.,** Kivell, B. M., Laugesen, M. & Grace, R. C. (2016) Changes to smoking habits and addiction following tobacco excise tax increases: a comparison of Māori, Pacific and New Zealand European smokers. *Australian and New Zealand Journal of Public Health*, 41 (1), 92-98.

**Tucker, M. R.,** Laugesen, M. & Grace, R. C. (2017) Estimating demand and cross-price elasticity for Very Low Nicotine Content (VLNC) cigarettes using a simulated demand task. *Nicotine and Tobacco Research*, Epub ahead of print.

**Tucker, M. R.,** Kivell, B. M., Laugesen, M. & Grace, R. C. (2017) Using a cigarette purchase task to assess demand for tobacco and nicotine-containing electronic cigarettes for New Zealand European and Māori/Pacific Island smokers. *New Zealand Journal of Psychology*, 46(2), 108-105.

**Tucker, M. R,** Bullen, C., Laugesen, M. & Grace, R. C. (2017) Subjective Effects and Simulated Demand for Electronic Cigarettes in First-Time Users: Effects of Nicotine Level. *Manuscript submitted for publication.*

**Tucker, M. R,** Bullen, C., Laugesen, M. & Grace, R. C. (2017) An Investigation into the Effect of Varying Nicotine Content on Electronic Cigarette Subjective Ratings and Demand over a Two Week Period. *Manuscript submitted for publication.*

### Presentations Associated with This Thesis

**Tucker, M. R.** (2015) Changes to smoking habits and addiction following two annual tobacco excise tax increases. *Psychology Students Conference, November 16<sup>th</sup> 2015, University of Canterbury, Christchurch, New Zealand.*

**Tucker, M. R.** (2015) Changes to smoking habits and addiction following two annual tobacco excise tax increases. *UCSA Canterbury Postgraduate Showcase 2015, November 19<sup>th</sup> 2015, University of Canterbury, Christchurch, New Zealand.*

Grace, R.C., **Tucker, M. R.** & Laugesen, M. (2016) Price, Products and Preferences: Results of the Cost of Smoking Study. *The Tobacco Control Research Tūranga: Ideas, Innovation & Impact, 25<sup>th</sup> May 2016, Auckland Conference Centre, Auckland, New Zealand.*

**Tucker, M.R.,** Bullen, C., Laugesen, M. & Grace, R.C. (2017) Subjective Effects and Simulated Demand for Electronic Cigarettes: Effects of Nicotine Level. *Society for Nicotine and Tobacco Research 2017 Annual Meeting, Firenze Fiera Congress and Exhibition Centre, Florence, Italy.*



## Appendix 2: Ethics Approval Documentation



### HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen  
Email: [human-ethics@canterbury.ac.nz](mailto:human-ethics@canterbury.ac.nz)

Ref: HEC 2013/167

20 December 2013

Professor Randolph Grace  
Department of Psychology  
UNIVERSITY OF CANTERBURY

Dear Randolph

The Human Ethics Committee advises that your research proposal "Cost of smoking study - additional data collection" has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 19 December 2013.

Best wishes for your project.

Yours sincerely

A handwritten signature in black ink, appearing to read 'L. MacDonald'.

Lindsey MacDonald  
*Chair*  
*University of Canterbury Human Ethics Committee*



# HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen  
Email: [human-ethics@canterbury.ac.nz](mailto:human-ethics@canterbury.ac.nz)

Ref: HEC 2015/18

26 March 2015

Megan Tucker  
Department of Psychology  
UNIVERSITY OF CANTERBURY

Dear Megan

The Human Ethics Committee advises that your research proposal "Comparison of demand and breakpoint for very low nicotine content (VLNC) and own brand cigarettes" has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 11 March 2015.

Best wishes for your project.

Yours sincerely

Lindsey MacDonald  
*Chair*  
*University of Canterbury Human Ethics Committee*



Health and Disability Ethics Committees  
Ministry of Health  
Freyberg Building  
20 Aitken Street  
PO Box 5013  
Wellington  
6011

0800 4 ETHICS  
hdec@mh.govt.nz

14 May 2015

Randolph Grace  
Department of Psychology  
University of Canterbury  
Private Bag 4800  
Christchurch 8041

Dear Grace

Re:	Ethics ref:	15/NTB/56
	Study title:	The impact of nicotine content on preference, subjective effects and patterns of use of electronic cigarettes in smokers not willing to quit.

I am pleased to advise that this application has been approved by the Northern B Health and Disability Ethics Committee. This decision was made through the HDEC-Full Review pathway.

#### Conditions of HDEC approval

HDEC approval for this study is subject to the following conditions being met prior to the commencement of the study in New Zealand. It is your responsibility, and that of the study's sponsor, to ensure that these conditions are met. No further review by the Northern B Health and Disability Ethics Committee is required.

#### Standard conditions:

1. Before the study commences at *any* locality in New Zealand, all relevant regulatory approvals must be obtained.
2. Before the study commences at *any* locality in New Zealand, it must be registered in a WHO-approved clinical trials registry (such as the Australia New Zealand Clinical Trials Registry, [www.anzctr.org.au](http://www.anzctr.org.au)).
3. Before the study commences at a *given* locality in New Zealand, it must be authorised by that locality in Online Forms. Locality authorisation confirms that the locality is suitable for the safe and effective conduct of the study, and that local research governance issues have been addressed.

#### After HDEC review

Please refer to the *Standard Operating Procedures for Health and Disability Ethics Committees* (available on [www.ethics.health.govt.nz](http://www.ethics.health.govt.nz)) for HDEC requirements relating to amendments and other post-approval processes.

Your next progress report is due by 13 May 2016.

Participant access to ACC

The Northern B Health and Disability Ethics Committee is satisfied that your study is not a clinical trial that is to be conducted principally for the benefit of the manufacturer or distributor of the medicine or item being trialled. Participants injured as a result of treatment received as part of your study may therefore be eligible for publicly-funded compensation through the Accident Compensation Corporation (ACC).

Please don't hesitate to contact the HDEC secretariat for further information. We wish you all the best for your study.

Yours sincerely,



Raewyn Sporle  
Chairperson  
Northern B Health and Disability Ethics Committee

Encl: appendix A: documents submitted  
appendix B: statement of compliance and list of members

**Appendix A**  
**Documents submitted**

<i>Document</i>	<i>Version</i>	<i>Date</i>
CV for CI: Randolph Grace CV 2015	1	04 March 2015
Protocol: Study Protocol for Electronic Cigarettes and Nicotine Content Study	2	04 May 2015
Survey/questionnaire: Questionnaires for Electronic Cigarettes and Nicotine Content Study	1	04 March 2015
Evidence of scientific review: Evidence of scientific review - grant application confirmation letter.	1	16 March 2015
Response to further information requested following provisional approval 14th April 2015	1	05 May 2015

**Appendix B**  
**Statement of compliance and list of members**

Statement of compliance

The Northern B Health and Disability Ethics Committee:

- is constituted in accordance with its Terms of Reference
- operates in accordance with the *Standard Operating Procedures for Health and Disability Ethics Committees*, and with the principles of international good clinical practice (GCP)
- is approved by the Health Research Council of New Zealand's Ethics Committee for the purposes of section 25(1)(c) of the Health Research Council Act 1990
- is registered (number 00008715) with the US Department of Health and Human Services' Office for Human Research Protection (OHRP).

List of members

<i>Name</i>	<i>Category</i>	<i>Appointed</i>	<i>Term Expires</i>
Mrs Raewyn Sporle	Lay (the law)	01/07/2012	01/07/2015
Mrs Maliaga Erick	Lay (consumer/community perspectives)	01/07/2012	01/07/2015
Mrs Phyllis Huitema	Lay (consumer/community perspectives)	19/05/2014	19/05/2017
Miss Tangihaere Macfarlane	Lay (consumer/community perspectives)	19/05/2014	19/05/2017
Mrs Kate O'Connor	Non-lay (other)	01/07/2012	01/07/2015
Mrs Stephanie Pollard	Non-lay (intervention studies)	01/07/2012	01/07/2015
Dr Paul Tanser	Non-lay (health/disability service provision)	01/07/2012	01/07/2015

<http://www.ethics.health.govt.nz>